DISCOVERY

A Monthly Popular Journal of Knowledge

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A Monthly Popular Journal of Knowledge

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Notes of the Month.

Discovery has always claimed to be the enemy of jargon, both literary and scientific, and in its columns we have aimed at presenting facts in language understandable by any one of normal education. With a world-wide circulation, we hope to have done our share in spreading the use of the English language at its best. A leading article in *The Times* of June 12th describes an effort to broadcast the language still more widely, in the form of "Basic English," which readers of *Discovery* will remember was described in our columns by Mr. C. K. Ogden in September, 1933. "The citizen of to-day," Mr. Ogden said, "is the victim of new forms of Word Magic so universal and so subtle that he is unable ever to escape their influence. The Babel of a thousand languages will soon assail him on the ether. . . .Is it not time for Grammar . . . to be cultivated once again?"

* * * *

Science, it has been well said, is the greatest internationalising force in the world to-day; and it is a remarkable thing that for the expression of the ideas of advanced science, standardised terminologies are in existence already. It is for the simpler expressions that Basic English would be of use; and a method of its application has already been evolved. Beyond the 850 words which make up the standard vocabulary of "Basic," an extra 100 words have been selected to provide a general scientific vocabulary, and for any branch of science of sufficient importance 50 special words have been added, making a maximum total of 1,000 words to lead up to the already standardised technical vocabulary. At present a knowledge of a score or so of languages is necessary to keep pace with scientific research; how much better it would be if the energy expended in this could be directed to more practical ends. Moreover, the need for keeping within the limits of a Basic vocabulary would make lucidity essential; and we should be spared such tangles of jargon as that which *The Times* quotes from an official text, and which we reprint as a horrid example:—

"The unity of views of the participants in the conversations has been established regarding the exceptional importance at the present time of an effective realisation of an all-embracing collective organisation of security on the basis of the indivisibility of peace."

* * * *

An excellent instance of clear exposition and the avoidance of scientific jargon is afforded by the Boyle Lecture on Problems in Experimental Embryology, delivered in May by Professor Julian Huxley and now published by Humphrey Milford at the Oxford University Press (price 1*s.*). This branch of biology is a science of growing importance; its wonders must be read of to be believed by the layman. What is still more significant is the point that Professor Huxley leads up to: that the isolation of experimental embryology is fast disappearing and its connection with other branches of biological science, such as chemical physiology and genetics, is being shown by research and experiment to be growing closer. The lecture is well worth study both for its matter and for the manner of its presentation.

* * * *

Over half a million tourists visited Canada's National Parks during last season. These natural playgrounds are now eighteen in number and embrace an area of more than 12,000 square miles, in which not only is the beauty of mountain, stream, and lake preserved in its

primeval state, but the flora and fauna as well are being conserved for the benefit and enjoyment of this and future generations. Wild animal life in all its various forms finds sanctuary and haven within the limits of the national parks, and to humans they provide an " Eden " where the sanctity of nature has been unspoiled by the march of time. Increases in the number of visitors are reported in all quarters, from British Columbia to Nova Scotia, while the Riding Mountain Park, in Manitoba, attracted over 100,000 tourists. A forthcoming article in *Discovery* will give those who are not lucky enough to be able to visit these animal sanctuaries some idea of the progress made in the preservation of wild life in Canada.

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Mr. Ormsby-Gore's cogent appeal for the preservation of Avebury and its surroundings from the encroachments of modern civilisation left little to be said on the necessity for its further exploration in the interests of archæology. As one of the greatest of prehistoric centres in Europe, it would indeed be a misfortune and a reproach to the nation if the bungalows and petrol pumps which threatened Stonehenge, until it was acquired as a national possession, should be allowed to overrun the characteristic Wiltshire landscape that gives an appropriate setting to the great prehistoric complex of which Avebury Circle is the centre. It would be no less a catastrophe if the unchecked development of the land in private hands were permitted to create an obstacle to the further exploration which current research shows to be increasingly necessary for the elucidation of early cultural and racial movement in prehistory of Western Europe. It is indeed open to question whether Mr. Ormsby-Gore, in suggesting the application of a scheme under the Town and Country Planning Act, has not been too moderate in his proposals. A monument of such transcendent importance should be a national possession.

* * * *

Some of the addresses given at the Summer Meeting of the Society of Chemical Industry's Food Group, held at Norwich last month, provide interesting comment on the article on the Detection of Milk Frauds in the June issue of *Discovery*. Dr. T. Ruddock-West, Medical Officer of Health for Norfolk, dealt with requirements for a clean milk supply. He also made some criticism of the present attitude of Public Health Authorities to the testing of milk supplies. Only tested milk, he said, should be placed on the market in a raw state and as the purchaser was entirely dependent upon the Authorities with their facilities for testing supplies, much more sampling should be undertaken than was done at present. If the milk was not passed as fit for consumption in the raw state it should be sterilised for, if efficiently carried out, the process was an excellent safeguard. The speaker recommended that pasteurising plants should be established and be subject to strict supervision.

* * * *

Mr. Davidson Pratt in a lecture given before the British Science Guild on June 12th, stressed the importance of educating the civil population in methods of defence against gas attacks in war, more especially from the air. Defence against chemical war is particularly urgent and important in spite of the prohibition contained in the Geneva Protocol, because a country with a well-developed air service and a strong chemical industry has the means for a rapidly improvised gas attack on the nerve centres of its enemy. A second reason is that gas has a devastating effect on the morale of people ignorant of its properties and uninstructed in methods of defence, and a country's lack of preparation to defend itself against gas might well induce an enemy who had the means to attack ready to hand to use gas in order to secure a speedy victory.

* * * *

Reduced to its simplest elements, the scheme of gas defence requires that the general public should keep out of contact with gas, whether as liquid or vapour, by staying in gas-protected rooms till the raid is over and the area cleared up, and that there should be an organisation for the de-contamination of the areas affected and the first-aid treatment of those who have been exposed to gas. As the success of the scheme will depend entirely on the behaviour of the population, education in gas-defence measures, the lecturer said, is therefore essential, and it is comforting to know that the Government is taking the steps which in its opinion will best achieve the desired end.

* * * *

Messrs. Frederick Warne & Co., have issued two series of Nature Observation Pictures in the form of folders, handily packed (if so desired) in a wallet containing four folders. The first two series illustrate British Birds and British Wild Flowers and the subjects have been judiciously chosen by Enid Blyton; her judgment is well seconded by the skilful reproduction of the coloured plates from the well-known " Wayside and Woodland " series. These excellent guides to the beginner in the study of nature observation are supplied at 6*d*. each folder mounted on paper, or 9*d*. on card; the price of each wallet is 2*s*. or 3*s*. according to the nature of the mounting.

Three-Colour Cinematography.

By Major Adrian Bernard Klein, M.B.E.

"The coming year is likely to be a decisive one in the history of the coloured film," says Major Klein in his summing up. Most of us have seen and marvelled at the progress of colour cinematography, but there is not a little vagueness regarding the processes involved. The explanation of the steps which have led up to the present position makes a fascinating story.

THE fundamental requirements for the solution of the problem of photography in natural colours have been known to scientists for the last fifty years, but it is only within the last five years that inventors have succeeded in devising technical methods simple enough to promise general application. The systems so far invented for still or motion picture photography are easily classified once certain principles have been grasped.

There is a marked desire on the part of the public to know how contemporary technical successes are obtained, and it is the duty of those who possess specialised information to explain how a certain result is obtained so simply that anyone of average intelligence will gain an accurate conception of the relation of theory to practice in any given process. Yet the task of the expounder in the special case of colour photography is particularly difficult, no doubt because of the wide range of sciences contributing to the solution of the problem. Frequent reference is necessary to a complex of data derived from the sciences of physics, chemistry, physiology, and psychology. Simplified description is difficult in the case of any modern technique of reproduction by a transformation process, a typical example being radio broadcasting, wherein original sounds (air-waves) are transformed into electrical impulses, and ultimately back into sound waves again, which stimulate in the final hearer sensations approximately identical to those which would have been awakened by the original sound waves. The reproduction of the appearance of the visible world is an equally complicated transformation process.

Colour Sensations.

In the science of colour photography we are endeavouring to stimulate an observer's eye by radiations (reflected from a white screen or a two-dimensional surface of some kind) intended to awaken approximately the same sensations of vision as the original light would have done. To-day the light from an electric arc can be so directed and modified as to form an image, in movement, on a screen, which is perceived by an observer to bear a close resemblance to nature, if indeed it does not constitute an absolute illusion of visible reality. How is this done?

Historically the first steps were not taken until a generally accepted theory of colour vision had been elaborated. Various theories have been advanced to account for the manner in which the eye responds to radiation, but it is now a generally accepted fact that our sensations of colour are derived from the stimulus of at least three simple or primary colour responses. The most universally accepted theory is that every sensation of colour is the resultant of the stimulation to a greater or less degree of three simple responders, but the precise physiological structure of the visual apparatus is still largely a matter of conjecture. In 1801, Dr. Thomas Young (1773-1829), in the Bakerian Lecture before the Royal Society, propounded the theory which now, as the result of the latter work of Helmholtz, commonly bears the name of the Young-Helmholtz theory of colour vision. He showed by experiment that there were three colour sensations, Red, Green, and Blue, which could not be aroused by the admixture of any other coloured lights. The original experiments were carried out with coloured rays isolated from the spectrum band produced by the dispersion of a beam of white light by a glass prism. It was found also that every other colour could be matched by the admixture in various proportions of the three primaries.

Early Filter Methods.

In possession of these facts early experimenters (Clerk Maxwell, Ducos du Hauron) must have approached the problem somewhat thus: we have learnt how to fix images of the visible world in gradations of the scale, white—grey—black, and the densities recorded bear some relationship to the apparent luminosities of the various colours of nature. How can we cause the photographic process to repeat the behaviour of the eye in all respects including the sensation of colour? Evidently we must first divide the visible radiation into three distinct groups of waves, and let these be caused to form a record of the proportion in which each of the primary sensations would be stimulated by the original light of a given part of the image. We must filter, or analyse, the light into three wavelength groups. The simplest kind of analyser will be a gelatine filter stained with an appropriate aniline dye, or dyes. We must make a red, a green, and a blue filter, and these must be placed one at a time in front of the lens of the camera, or

somewhere in the optical system, to act as a selector, or analyser, during the exposure of the sensitive photographic emulsion to light. Next, we must have a photographic material which is capable of recording radiation of any colour (that is, sensitive throughout the whole visible spectrum) which the analyser may transmit. Then let us take three pictures of the subject, using the three filters. One negative will constitute a record in terms of black and white of the red sensation-causing light in the original subject, another the green record, and the third the blue. Now let us make ordinary black and white positives from these negatives and with a triple magic lantern let us project these one on top of the other upon a screen, projecting the positive of the red record through a red filter, the green through a green filter, and the blue through a blue filter. The respective coloured lights in their varying analysed quantities will thus be added together, and the final combined image should recompose the original colours of the subject photographed. Thus, or somewhat thus, was the logic of their thinking. And they were right, for, although the first attempts were rough, the combined pictures of coloured light did resemble the original subject.

By this means the three positives were controlling, by their variable densities, the stimulation value of the red, green, and blue sensation in all parts of the original image, and the colour filters were providing the character of the primary sensations. Every part of the triple combined image represented various combinations of the three primary colours. Where all three plates happened to be transparent in the same part of the picture, there was transmitted to the screen the full value of red, green, and blue light from the sources of light in the three lanterns. The resulting sensation for the observer of that part of the image was white. Various other relative percentages of the three primaries gave every other possible colour sensation.

When these principles have been grasped, the theory of the subsequent attempts to solve the problem will be readily understood. First there must be the analysis of the light into the three primary elements; then the photographic recording of these elements separately; finally the reproduction, or synthesis, accomplished by combination of the primary colour elements in terms of their original values. This is a sequence not unlike the artificial chemical synthesis of a natural compound.

Mosaic Film.

It was a logical stage in the development of method that it should early be proposed to divide the photographic record into a large number of semi-microscopic primary filter elements, instead of making three separate "continuous" records. From this idea were evolved the well-known "screen" or "mosaic" processes, in which the photograph is recorded through a regular or irregular pattern of coloured rulings or grains. With such methods it has always proved very difficult, if not impossible, to print *facsimile* copies. All photographers are familiar with the Lumière and Agfa colour-screen plates and films, the Spicer Dufay process (Dufaycolor), and the Finlay screen plate process. In the latter process the ruled colour screen is on a separate plate which is exposed in contact with the photographic plate; from the negative so exposed a transparency print in black and white is made, and this is finally viewed bound in register with a ruled colour screen plate similar to that which was used when the negative was exposed. Dufaycolor is a derivative of the Dufay screen plate. In this process a film upon which has been printed an extraordinarily fine regular tri-colour pattern is coated with a high-speed panchromatic emulsion, the film base being non-inflammable cellulose acetate. Sixteen-millimetre film was first sold to amateur cinematographers in 1934 with considerable success. More recently some work has been done for full-size commercial film in some recent productions. The copies still leave a good deal to be desired, but considerable progress has been made towards a solution of this problem. The manufacture of Dufaycolor film on a commercial scale is a triumph of photographic technology, for the difficulties which had to be surmounted were immense. This is obvious when we consider that the pattern consists of over one million individual colour elements per square inch. Much credit is due to Ilford Limited, who are responsible for manufacture in this country.

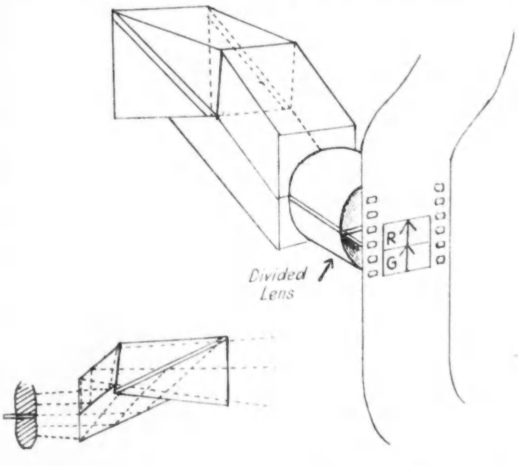
Lenticular Film.

In one variation of the screen process known as "lenticular" film, the micro-colour elements are produced optically by minute corrugations physically impressed upon the celluloid. The function of these embossings is to act as cylindrical lenses, and to focus images of a filter divided into three parallel bands, which is placed just in front of the lens. In effect the lenticular process is similar to a screen process in that the image is subjected to an analysis by myriad elements of red, green, and blue, which, in this case, are recorded on the emulsion as parallel lines of varying density, depending on the value of the coloured light in that part of the image. When lenticular film is projected for synthesis the light retraces its path refracted by the embossings, and, having passed through the colour filters on the projection lens, an image is obtained upon the screen consisting of fine parallel lines of red, green,

and blue. These lines will vary in their brightness in accordance with the density at any point of the black and white lines on the positive film. Thus, both for taking and projecting the picture, the "screen" is produced by entirely optical means, no colour being found on the film at any stage of the process, the colour being provided by the filters on the lens. This process has been commercialised for amateur cinematography under the name of "Kodacolor" by the Kodak Company, and very beautiful results have been obtained. For full-sized film immense efforts have been made to commercialise lenticular film, so far without marked success for various technical reasons, such as difficulties in copying, lack of depth of focus, and parallax.

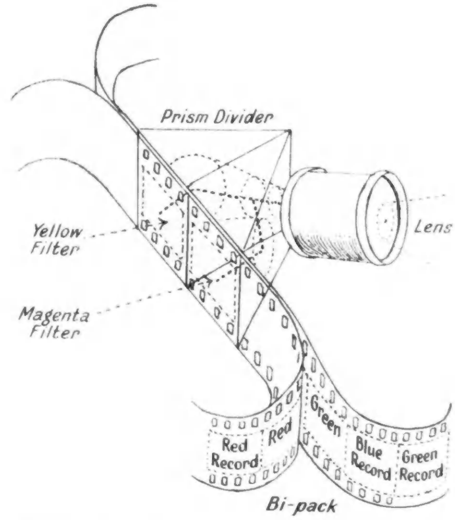
The systems may be divided into two as far as the photographic analysis is concerned: those which make use of three colour-separation negatives, and those which make use of a single picture subdivided into a microscopic pattern of primary records. Systems are distinguished far more by the variety of methods which have been used to accomplish the synthesis, namely, the completed positive colour print. In this article, as we are confining ourselves to cinematography, the methods for making the print on paper will not be discussed; even so, the differences between opacities and transparencies concern only minor points of photochemical craftsmanship. In the case of motion pictures we have to consider the methods by which colour transparencies can be made upon film, or, on the other hand, the methods by which the synthesis can be attained by optical projection.

Let us take the first of these two alternatives. Clearly



Iceland spar "Raycol" beam-splitter (Bellingham and Stanley patents), entirely free from parallax. This system may be employed with bi-pack to obtain three-colour negatives.

the final colour transparency may be either a coloured picture infinitely gradated, or it may be a mosaic pattern of micro-colour elements. The large majority of processes belong to the former class. Suppose, then,



Three-colour negatives from two films. The films travel in a plane at 45° to the lens, necessitating a special camera. The camera gate must be twice the normal width and the film moved two pictures for each exposure.

that we have obtained three colour-separation negatives by one of several methods referred to later, we must now consider the following requirements with which all inventors of colour processes have been faced.

The gradations of black and white of a positive print made from a colour-separation negative represent the light which was *not* recorded on the negative. Used as a transparency placed in front of a source of light it functions as an absorber of the particular primary colour recorded on the negative from which it was made. To this end the positive print must be rendered in such a colour as will be transparent to the remainder of the spectrum unrecorded on the negative, and opaque to the colour which was recorded. In brief, from the three negatives three positives are made, each in the colour complementary (*viz.*, the balance of the spectrum) to the light recorded on the negative used. When assembled in superposition we have in fact made an infinitely variable three-colour subtractive filter which can be placed between the eye and a source of white light. Thus the red-filter negative has to be printed in green-blue (turquoise), the green filter negative in red-blue (magenta), and the blue filter negative in red-green (yellow). Now, these three colours, turquoise,

magenta, and yellow, are not really primary colours because each represents two-thirds of the spectrum, but they can be termed the primary *subtractive* colours because all colours may be matched by their subtractive admixture. They are, in fact, the traditional primary colours of artists, namely, red, yellow, and blue, although artists did not understand the laws of the physical admixture of paints, when they called these the primaries. It is only in recent years that it was realised that the red should be a cerise pink or magenta, and the blue a turquoise.

Thus it is that we can recompose colour either by adding primary coloured lights to black (by projection on to a screen in a dark room), or by *subtracting* primary coloured lights from a white light (or surface capable of reflecting white light) containing all colours. In each case the result is identical, but the coloured elements used in the latter case have a minus value. Processes can thus be classified as *additive* or *subtractive*.

Subtractive Processes.

The methods which have been proposed for making the multi-colour subtractive (colour-on-film) print are innumerable. Among other methods we might cite :—

Chemical toning of the silver print on single- or double-coated film.

Mordanting the silver print and dyeing.

Wash-out bichromated pigment-gelatine relief processes, with subsequently dyed reliefs.

Wash-out gelatine relief by development tanning, used for making matrices for obtaining " imbibition " dye transfer prints on blank film, or upon black-and-white lightly printed.

The last method is employed by " Technicolor," an American process for the making of three-colour prints by three dye impressions from gelatine reliefs, known as " imbibition." In the latest phase of " Technicolor " these three impressions are printed on top of a grey " key " or lightly printed silver positive—an extremely delicate and difficult piece of processing. The result has been very successful, and several feature films are now being made in Hollywood by this process. The popular " Silly Symphonies " of Walt Disney are all printed in three-colour " Technicolor," for the printing of which this process was employed for the first time.

It is doubtful whether the other methods of making a colour print can be used for three-colour without re-coating and re-sensitising the film after the first two printings, or else having recourse to transfer or cementing of two films. Such systems are probably applicable only to two-colour processes, which we may now regard as obsolete. However, some very promising results have recently been shown by sponsors of the Brewster process, in which an imbibition printing of yellow is superposed on a toned double-coated film.

Other than " Technicolor " and the Brewster process, the only commercially developed three-colour subtractive process is " Gasparcolor." The latter process makes use of film coated with three layers of coloured emulsion, one blue-green, one magenta, and one yellow. The three emulsions are sensitised to different lights, and so may be independently " printed." By ingenious chemical means the dyes in the layers are decolorised where the images have been printed and developed, the final print consisting of three layers of transparent coloured gelatine ; a result as perfect as if three ideal coloured reliefs had been cemented together (as in the carbon process for example). The " Gasparcolor " process is the invention of Dr. Bela Gaspar, a Hungarian chemist—who has spent some ten years in its development. Much will be heard of this remarkable process in the near future. Production has already begun in England.

Recently Kodak have introduced a very interesting three-colour subtractive film for sub-standard cinematography which is to be known as " Kodachrome." The process has so far been applied only to 16 mm. film, and there is little likelihood of this type of film being used for commercial 35 mm. film chiefly owing to copying problems. As in the case of most amateur film, the original film exposed in the camera is reversed and used for projection, but the image when completed is in continuous tone colour, all silver being removed, and as there is no screen the definition is very good. The films are already available in America, and will be obtainable in this country as soon as the necessary processing plant is installed.

An Interesting New Method.

The process is based upon the patents of Messrs. Leopold Mannes and Leo Godowsky, and it has been worked out in the research laboratories of the Eastman Kodak Company, Rochester, U.S.A. The film receives five coatings :

Top layer ..	Blue-sensitive emulsion (containing yellow dye).
	Plain gelatine.
	Green-sensitive emulsion.
	Dyed gelatine filter (red).
Bottom layer	Red-sensitive emulsion.

The top layer transmits green and red light to the two lower layers, but no blue (absorbed by yellow). The second layer being orthochromatic (green-sensitive) records green only, no blue light getting through the top emulsion. Only red light reaches the bottom layer.

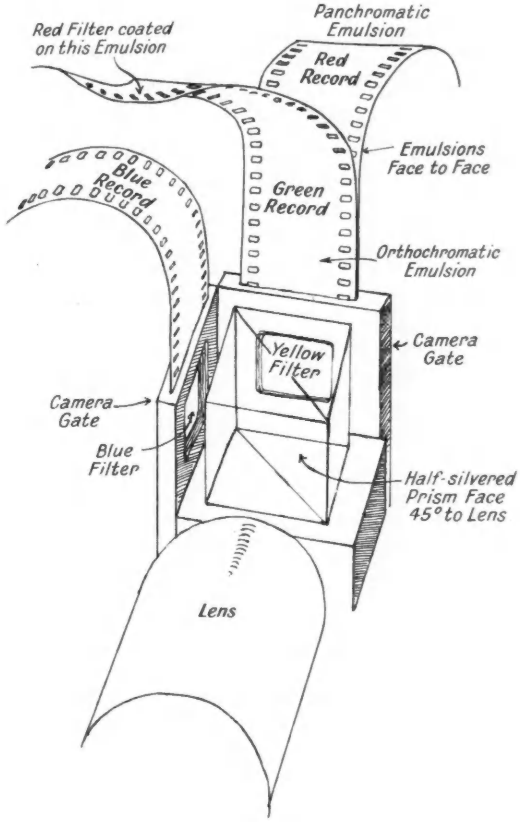
Processing is divided into several stages, each being

carried out on a separate machine. The first stage is reversing. The film is developed, bleached, cleared, exposed to light, and re-developed. By the action of the second developer a blue-green dye is formed in the neighbourhood of the silver developed. At this stage all three emulsion layers have been developed to blue-green images. The film is then dried. Next, the blue-green is removed from the middle layer and a magenta image converted from the blue-green. The same change occurs in the top layer. The top two layers are converted into silver chloride by a suitable bleach which destroys the blue-green. After exposure to light the top two layers are re-developed and transformed by a dye-coupling developer into magenta. We now have blue-green at the bottom, and magenta in the top two layers. The operation is repeated again for the top layer, which is finally transformed into a yellow image. In the last stage the silver is entirely removed, dye images alone remaining.

This is, in effect, a reversible tri-pack, with emulsions containing dye-forming agents by which the dye can be formed and retained where the silver is developed and in proportion, naturally, to the quantity of silver developed. It will be observed that the principle of the chemical sequence is exactly the opposite of Gasparcolor, in which the dyes are already present in the three layers of the emulsion, and are subsequently *destroyed* where the silver has been developed.

Additive Processes.

The second alternative of synthesis is by additive optical projection. From a purely theoretical point of view this method offers certain attractive advantages, but the practical difficulties are almost insuperable. The earliest attempts were made by the Gaumont Company before the war, when a film was projected upon which three separate small pictures, occupying a somewhat greater length of film than the normal picture, had been printed. The projector had three objective lenses, each with one of the three primary colour filters in it. The three images were carefully superimposed in registration on the screen. The film was printed in black and white, the colour being obtained from the colour filters on the three separate objective lenses of the projector. The camera was equipped with three lenses one above the other, no attempt being made to overcome the serious parallax which must occur when the object is photographed from several points of view. In such optical systems it is absolutely essential for all three images to be derived from one lens, otherwise, in effect, the subject will have been photographed from more than one position, in consequence of which the angular relationship of subjects situated on various planes receding from the camera must differ. This geometrical lack of coincidence is known in optics as parallax, a fault inherent in a multitude of proposed



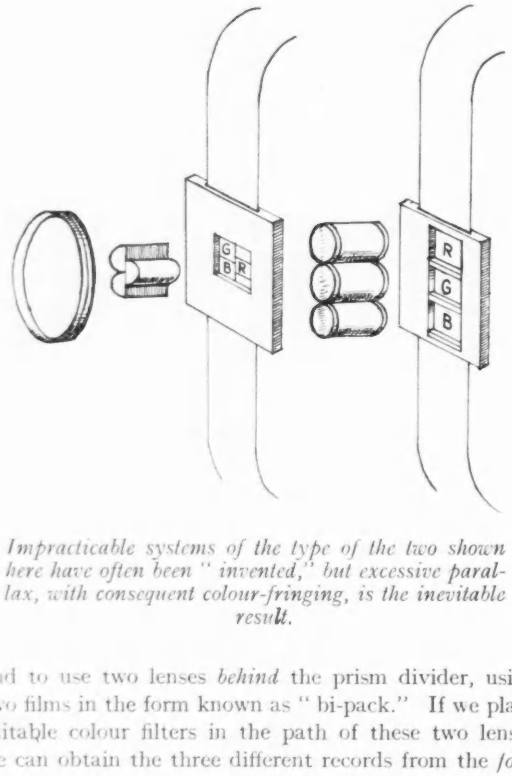
If a green filter is placed opposite the single film, and a magenta filter opposite the bi-pack (see lower sketch on p. 189), an alternative method is available. This is the arrangement employed in the "Technicolor" camera.

optical systems for obtaining three pictures simultaneously.

No three-colour additive process in which separate images are projected from one film has ever been commercially adopted. Such a process necessarily involves the replacement of the normal projection lens by an elaborate compound prism objective of some sort. Separate calibration and registration is required in every theatre and no one can guarantee that it can be removed and replaced without registration trouble being experienced. Several two-colour additive systems have been exploited commercially in recent years, among others, the "Raycol," "Cinecolour," and "Hillman" processes,

but the above difficulties have prevented their wide application.

The problem is to obtain three geometrically identical negatives. There are two alternatives: to divide the rays coming from the object by some prism system and to use two or more lenses; or to use one lens and divide the beam between the lens and the film. The latter method is probably impossible on one film, taking into consideration the short focus lenses often employed in modern studio technique. There simply is not room for the prism system between the lens and the film. The former alternative is alone practicable. Perhaps the best method is to divide the original ray into two,



Impracticable systems of the type of the two shown here have often been "invented," but excessive parallax, with consequent colour-fringing, is the inevitable result.

and to use two lenses *behind* the prism divider, using two films in the form known as "bi-pack." If we place suitable colour filters in the path of these two lenses we can obtain the three different records from the *four* pictures recorded on the *pair* of films. The method generally employed is to use yellow and magenta filters. We shall obtain from the ordinary bi-pack the green and blue records from the front orthochromatic film, and a red record on the rear panchromatic film. Such beam-splitter cameras as the "Raycol" and "Cinecolour" could be used in this manner.

A method which has been made use of for the "Technicolor" process is to use three films, two in the form of a bi-pack and one single film; a right-angle half-silvered prism is used in conjunction with two camera gates at 90 degrees to each other. Such a system will give excellent results, but the camera is necessarily elaborate and expensive.

A novel type of camera is employed for the Brewster Process. In this camera interlocking propeller reflectors so cut the beam from a single lens that the exposure is made simultaneously on two film gates, presumably at right angles to each other as in the Technicolor camera; similarly two films (bi-pack) would be run in one gate and a single film in the other. It is possible that the moving reflectors may be more efficient than half-silvered surfaces such as have to be used in prism beam dividing systems, in which much valuable light is lost.

The coming year is likely to be a decisive one in the history of the colour film. Whether there will be a prolonged struggle between additive and subtractive processes remains to be seen. On the whole the balance of advantage would seem to be on the side of the subtractive (colour-on-film) processes, but it is rash to prophesy the course of evolution in an industry which has seen so many technical revolutions during the last few years. We may expect further improvements in the negative technique. It is certain that the beam-splitter camera is not an elegant solution of the problem of making three-colour negatives. Such cameras are very expensive to make and require constant adjustment to preserve focus and registration of the multiple images. The advantages of being able to use a standard camera are enormous, both commercially and technically, and experiments are in progress which indicate that the normal camera can be used to record upon bi-pack three separate images on the two films.

Of existing subtractive three-colour processes Gasparcolor and Technicolor are at present farthest advanced. Both processes have achieved such perfection in colour printing technique that it is doubtful whether two-colour competing processes will survive for long. Technicolor will have the honour of having made the first three-colour full-length picture. This film is "Becky Sharp," from the story based upon Thackeray's "Vanity Fair." It will be shown in the near future in England. The reaction of the trade and of the public to this film is awaited with the greatest anxiety by those engaged in the development of the colour film. Indeed, it can be said that if it is the success which those who have seen it report, there will be great activity in all the British studios to catch up with the lead which, perhaps, the Americans will once more have established. In that case it is fortunate that in Gasparcolor we have a process immediately available in England which is capable of equalling and possibly surpassing Technicolor in both definition and accuracy of colour reproduction.

The Theatre at Verulamium.

By Kathleen M. Kenyon, M.A.

Among the important sites that have been excavated in this country during the last few years, the Roman city of Verulamium takes a premier place ; and its theatre, unique in Britain, is perhaps the most striking of the buildings explored. Miss Kenyon's first-hand account of the work done reveals many curious and interesting features in the history and construction of the building.

THE provision of amusements for the public formed an important part of the functions of the chief officials in a Roman city, and excavation has shown that throughout the Roman Empire towns even of comparative insignificance had buildings for this purpose. Most towns had both an amphitheatre, with seats all round an oval arena devoted to games and gladiatorial shows, and a theatre, which was semi-circular only, and where purely dramatic performances took place. In Britain, however, though a number of amphitheatres are known, the only theatre which has been discovered is that at Verulamium, near St. Albans. This was first identified in 1847 by Mr. R. Grove Lowe, a local antiquary. Though his excavations were excellently carried out for the period, it was clear that much more information could be obtained by modern methods of excavation, and the question of further examination of the building was raised in the course of the excavations on other parts of the Roman city. The Earl of Verulam, the owner of the site, was approached, and both he and Lady Verulam at once realised the importance of the question. Lord Verulam not only gave permission for the excavations to be carried out, but on his initiative the Gorhambury Estates provided the funds for a necessarily expensive undertaking. Both archaeologists and the general public owe Lord Verulam a great debt for this public-spirited action, especially as the building is to be kept permanently open.

Eighteen Centuries Ago.

The excavations, which were carried out in 1933 and 1934, have revealed a most interesting structure. The theatre stood near the centre of the Roman city, fronting on to Watling Street, its chief thoroughfare. The original building dates from between A.D. 130 and 140, which was the period of greatest prosperity and expansion at Verulamium, as was shown by the excavations in other parts of the city. A number of alterations carried out at various periods complicate the remains, but the original structure was simple. It consisted of a completely circular orchestra sunk into the ground, surrounded for more than two-thirds of its circumference by a steeply-sloping earthen bank on which would have been wooden seats. The remaining part of the circumference was clasped by a small stage building, which fronted on to the circular orchestra wall. The seating bank was supported externally by a substantial buttressed wall. This terminated on the side of the stage in massive piers, which doubtless carried statues or other architectural features. Originally, the side walls of the seating bank were carried straight across from there on the axis of the stage, thus forming a straight façade with a small stage building projecting in the centre, but at a slightly later period these walls were replaced by the oblique ones visible in the photograph. The supporting wall has been robbed down to the external ground level, and the earthen bank has collapsed and been denuded away to that level, so that the existing remains represent only that part of the building which was sunk into the ground. The seating bank was pierced by three gangways, which would have been vaulted over to carry the upper rows of seats. These led to the orchestra alone ; in the first period access to the seating bank was obtained only by external staircases, which were supported by larger buttresses.

Unusual Seating Arrangements.

It is at once apparent that this structure has many points of difference from the normal Roman theatre, the plan of which was stereotyped. In the primitive Greek theatre the only essential feature had been a circular dancing-place. The stage was added later, and though it steadily grew in importance, the circular orchestra was always prominent, and the stage did not encroach on its area. The auditorium surrounded about two-thirds of the orchestra, and was separated from the stage by the main entrances into the theatre. In the Roman theatre, however, the stage was the original feature, in front of which stood the spectators. The space immediately in front of the stage was early reserved for senators and other notabilities, and so, when seats were provided, their seats occupied this area. The Roman orchestra, therefore, was never an area where any action took place, and the seats were all arranged so as to have a good view of the stage and not of the orchestra. As all the performers were on the stage, instead of a large chorus being in the orchestra, the former had to be considerably larger

than the Greek stage. For both of these reasons the auditorium of the normal Roman theatre never appreciably exceeded the semicircle, for it is obvious that the more it approached a complete circle, the less the room left for the stage would be, while the additional seats, following the curve of the orchestra, would tend to face more and more away from the stage.

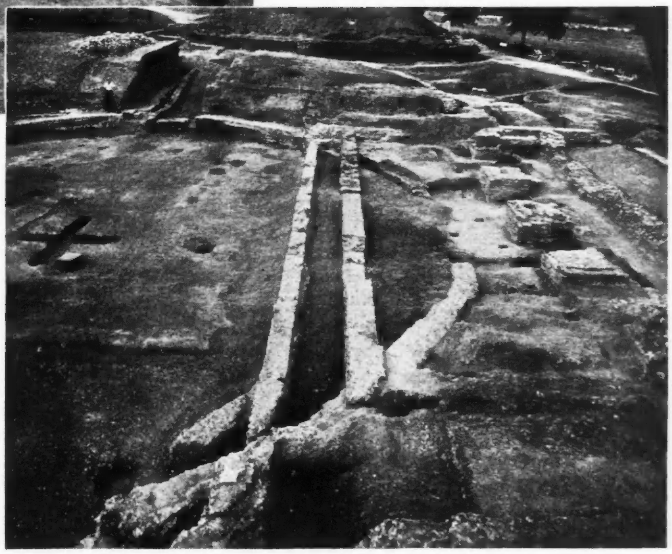
It is clear that the Verulamium theatre is not of this normal Roman type. All the seats beyond the transverse gangways face towards the centre of the orchestra, and to some extent away from the stage. The orchestra is completely circular, and the stage is almost insignificant in size, its width being only half the diameter of the orchestra instead of twice that length, which was the normal rule. It is in fact much smaller than the stage in the Greek theatre, for that is set back from the orchestra instead of clasping it, while the Greek auditorium always widened out from the true circle, so as to give a better view of the stage. Another point of difference is that in Verulamium the auditorium is pierced by a gangway opposite the stage, thus destroying some of the best seats, an arrangement never found in a normal theatre.

The theatre at Verulamium is therefore of an anomalous type. The points of resemblance to a Greek theatre are of course merely superficial, for no one would suppose that performances requiring a classical Greek chorus were given in second century A.D. Roman Britain. The resemblance comes merely from the fact that in both cases a considerable portion of the action took part in the orchestra. At Verulamium, in fact, a number of seats can have had almost no view of the stage, and the orchestra was clearly the more important area.

But, though the Verulamium theatre is not of the normal Roman type, it does not stand alone. There is a group of theatres in Northern France, in the Roman

An aerial view of the Verulamium Theatre, showing the post-holes in the original orchestra in which supports for the later wooden seats were fixed, the three gangways, and the new outermost wall of the seating-bank, added under Constantius Chlorus, at the end of the 3rd century.

Left: In the foreground is the external wall of the seating-bank, with its massive buttresses; on the left of the circular orchestra is the stage, while at the back and to the right are gangways leading into the orchestra.



Below: A close view of the stage, showing the later addition to it, where it encroaches on the circular orchestra; also the cross-shaped hole in the centre of the latter.

province of Gallia Comata, which have the same characteristics. They have the same large orchestra, though not always with the circle quite complete, the same very small stage, and usually gangways in the same position, and they were obviously devoted to the same kind of performances. An indication of one of the uses to which these buildings were put is given by a theatre at Drévant (Cher), where a number of dens for animals are found in the wall separating the orchestra from the auditorium. It is clear, therefore, that beast fights took place in them, but they can only have been on a small scale, quite unlike the usual shows in amphitheatres. The stage, too, small as it is, must have had some function, so these theatres cannot be classed as amphitheatres. Probably some kinds of games or dancing took place in which both stage and orchestra were employed. Another highly probable use is for cock-fighting, for which an amphitheatre would have been inconveniently large. Also in the centre of the orchestra at Verulamium was found a cross-shaped cutting in the ground, with a central depression which obviously held a central upright supported by two bed-plates. This may have been a gibbet, a maypole, or a post to which baited beasts could be chained.

It is very interesting that this type of theatre, which may perhaps be called a "cock-pit theatre," is confined to Northern Gaul and Britain. No examples are found outside this area, and of the considerable number of theatres within it, there are only two doubtful examples of the classical type, which is common in Southern Gaul. This distribution coincides exactly with that of the Romano-Celtic type of temple, and it is clear that both are the product of an area where Celtic influence was still strong enough to modify Roman institutions.

This peculiar and interesting type of theatre did not have a very long life at Verulamium, for between A.D. 160 and 170 alterations were made which had the effect of approximating it much more closely to the normal classical type. The chief alterations affected the stage, whose area was considerably increased by the construction of a wall forming a chord of the orchestra circle. The outer wall visible in the photograph is a later addition, but it almost certainly merely

replaces an earlier wooden structure, while between the two would have been a curtain, worked in the normal Roman method, by which both the curtain and telescopic posts supporting it descended into a slot between two walls in order to disclose the stage. The holes into which the posts were lowered were found, and are comparable with similar ones at Orange and elsewhere. At the same time the back of the stage was altered to resemble more closely the ordinary elaborately decorated Roman *scænæ frons* by the addition of three columns, flanked by two pilasters. A portion of a Corinthian capital belonging to one of the former was found. While the stage was thus being increased, a large part of the orchestra was converted into seating accomodation. This was supported on a wooden platform, the holes in which the posts whereof had stood being clearly visible in the ground. It was probably arranged in a series of low steps, on which the armchairs or thrones of the notabilities would be placed, as in the normal Roman orchestra. A minor alteration of this period was the construction of side stairways, leading off the lateral gangways, to give additional access to the upper seats. All these alterations were clearly made with a view to rendering the structure as much like the normal Roman theatre as the original building would allow.

The remaining history of the theatre reflects closely that of the rest of the city of Verulamium, and indeed of Roman Britain. Like many of the buildings in Verulamium, it seems to have required extensive repairs about the year A.D. 200, about the time when Septimius Severus came to Britain to restore order after a period of anarchy. Again, like the whole city, it fell into ruin during the second half of the third century, and had to be almost completely rebuilt at the end of the century, when Constantius Chlorus once more restored order. This rebuilding was on a very large scale, and a number of alterations was made. The most important of these was the addition of a new outer wall to the seating bank. The space between this wall and the original outer wall was doubtless made into a vaulted corridor, over which the upper rows of seating were carried. An interesting find belonging to this period was that of a hoard of 800 minims, small coins in some cases not more than 5 mm. in diameter, buried beneath the floor of the stage. These prove a point which had hitherto been doubtful, namely, that these coins were in circulation at the same time as the official coinage they imitate, which was found in abundance in the same level.

After this revival, the history of the theatre is a tale of gradual decay. From about the middle of the fourth century the area was given up to a rubbish dump, and the orchestra was found filled to a depth of five feet with refuse of all descriptions, including a surprisingly large number of coins of the period. There can be no more vivid commentary on the state of decay into which Roman Britain was falling than the fact that an important public building, in the centre of one of the principal cities of Britain, and fronting on Watling Street, one of the chief thoroughfares of the country, should have been put to such base uses.

The Origin of the English Channel.

By Friedrich E. Zeuner, Ph.D.,

Lecturer on Geology and Palæontology at Freiburg University.

The English Channel is commonly regarded as the most natural thing in the world. From the standpoint of a geologist, however, it is almost by chance that England is separated from the Continent, and this event occurred not long before the present age. Dr. Zeuner shows how the separation can be dated almost exactly.

THE history of the earth and of the life she carries has been traced back for more than 1,000 millions of years. We can say that for the whole of this time the area now covered by the British Isles has been a part of the Continent of Europe, although marine invasions often altered the distribution of land and shallow sea. The nearer we come to the present, the more we realise how the present distribution of land and water arose, but even when the Ice Age began, roughly 800,000 years ago, vast areas now submerged under the North Sea were an integral part of England, connecting it closely with the Continent of Europe. At that time, probably, the mouth of the Rhine was near the Dogger Bank, the Thames was its tributary and the Straits of Dover did not exist, but the western part of the Channel already separated Cornwall and Devon from Brittany and Normandy.

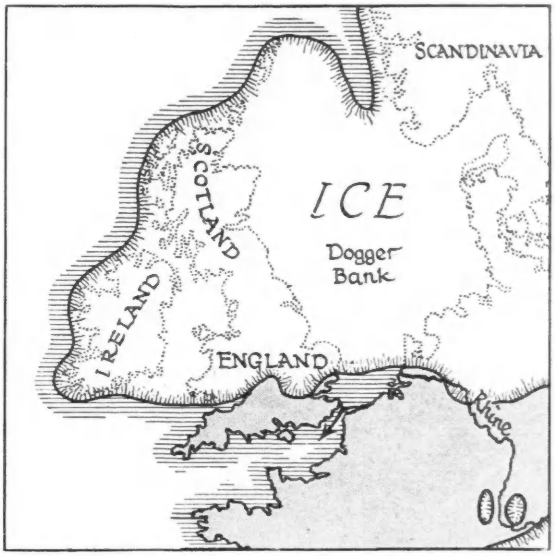
We know that during the Ice Age the climate became repeatedly colder and the glaciers formed large sheets of ice covering Scandinavia, the British Isles, and the

Alps. There is no doubt that the Scandinavian ice masses invaded Great Britain once at least, and there is no doubt, too, that the North Sea was covered by water several times. These conditions induced Clement Reid to think that at a time when the ice covered most of the North Sea the remaining water was dammed and temporarily had an outflow through the Straits of Dover—but, as yet, we have little evidence for it.

The detailed record begins after the end of the Ice Age, in early Postglacial times, about 12,000 years ago. Land covered large parts of the North Sea as in Preglacial times. The Straits of Dover were then a hilly land cut by streams and rivers, of which C. J. Gilbert has described the Rother, the Tillingham, and the Brede, as the most important. Together with rivers from Northern France they formed a transverse valley running near the northern versant of the "Wealden" dome, extending from Kent and Sussex to Boulogne. East of these "Strait Hills" extended vast plains rising little above sea-level and composed of mud deposited by the rivers discharging into the south-western North Sea. Thus, England was closely connected with Northern France, Belgium, and Holland at that time, and even with north-west Germany. But the Channel between Normandy and Brittany and Cornwall and Devon was, as mentioned above, a deep bay of the western Atlantic.

These facts were of the utmost significance in the immigration of the fauna and flora of the British Isles. A bridge existed which had allowed not only the glacial and interglacial animals and plants to immigrate into and to retreat from England in accordance with the manifold changes of climate during the Ice Age; it also enabled numerous members of the actual British fauna and flora to settle in Britain.

The important event of the separation, its time, and the climatic conditions of the Postglacial period may be dealt with on the following lines. We may wonder if it was possible to date such an event in years. It has not been easy to obtain accurate figures, but studies in archæology as well as in botany have enabled us to compare the history of the Channel with that of the Continent and Scandinavia, where a chronology in years has been established. There were two ways of determining the relative age of the subsidence of the "Strait Hills." The first one was to connect this event with the many finds of implements of prehistoric men: it resulted in the observation that the subsidence fell at the end of the Palæolithic Age. The second way was to compare the contents of the forests and the peat strata of pre-depression times, scattered over the British coasts and now submerged under the sea, with those of the Continental countries, and thus the climatic or floristic period was found in which the depression had taken place. Finally, on a comparison with Scandinavia, where geologists under the leadership of De Geer have counted backward for some 20,000 years,



Map showing the maximum glaciation in the Subatlantic period. The arrow indicates Clement Reid's theory of the outflow of what water was left unfrozen in the North Sea.

the strata left by the waters of the retreating glaciers allowed us to state that the country of the Straits of Dover began to subside about 8,000 years ago.

The process was comparatively quickly ended. The sea invaded the transverse valley mentioned above, and formed the first, still very narrow, communication between the waters on either side. Then another power started its action, a power that rapidly increased and finished the work initiated by a slight depression of the earth's crust: the tidal scour. As the tides do not coincide in the North Sea and the western Channel, the alternating current passing the Straits of Dover four times a day is extremely strong. Together with the action of the waves, produced by the power of the wind, the tidal scour widened the passage quickly, eating back the hills on either side and forming the cliffs well known to seaside visitors on the coast of Kent.

It seems, however, that the process was divided into two phases—as C. J. Gilbert has pointed out—and that after a certain time the depression stopped for a while. Thus, the "gorge" was formed, a deep submarine valley in the bottom of the Straits, now about 70 ft. deep. Later on, the depression continued, and the shores were eaten back until they reached the present

stage. The movement of the earth crust gradually died away, the whole submersion having been completed within a few thousand years.

But the waves did not only destroy, they also deposited sand and shingle at certain places. One of the most interesting localities is Romney Marsh, a country carefully investigated by C. J. Gilbert. He found that originally a bay was formed here. It gradually was filled with deposits derived from the cliffs on either side, especially those of Hythe and Folkestone, but also at Fairlight in the south-west. This is not the only change of the coastline by sedimentation. Many others have taken place, too, down to the present day, as (*e.g.*) the filling of the strait that separates the Isle of Thanet from the mainland. However, these are merely modifications of minor importance compared with the fact of the separation of England from the Continent.

It has already been shown that the climate was subject to considerable alterations throughout the Postglacial period. In the time of the last glaciation itself, when Scotland, North England, and Wales were covered with an ice sheet, the climate of the remaining part of the country was rather cold, with a long winter and a short but comparatively warm summer. Forests could hardly persist under these conditions, and the country was mainly covered with a vast steppe on which mammoths, rhinoceroses, saiga antelopes, and many other animals grazed. The glacial steppe may have persisted until about 30,000 or 20,000 years ago in England. Then the climate gradually became warmer, but still remained rather dry; it was of the continental type, with hot and dry summers and cold winters. This period is called the "Boreal Period," and lasted till 7,500 years ago.

The following climatic phase of the Postglacial period, the "Atlantic Period," was considerably damper than the Boreal. There was an oceanic climate, similar to the present climate of the British Isles, but considerably warmer. The maximum of temperature after the Glacial period fell at the Atlantic phase, and it is now cooler in Europe again.

During the Boreal and the Atlantic phases most of our common trees immigrated into the British Isles (willow, birch, pine, hazel, elm, oak, and elder), and with the beginning of the Atlantic phase the lime tree followed. This sequence of immigration was elaborated by the Swedish palæobotanist, G. Erdtman, who studied the fossil pollen of trees occurring in peat-bogs. Similar investigations were carried out in north-west Germany by F. Overbeck, among others, and they have enabled us to date the history of the submergence of the Channel Bridge precisely, from geological observations of the submerged forests of the North Sea, and on a comparison with the Postglacial history of Scandinavia, which is known the best.

In the eighth millennium B.C., *i.e.*, in early Boreal times, the Dogger Bank was still a part of the land, and it was gradually submerged after that. The Atlantic phase began about 5500 B.C.; the Straits of Dover did not yet exist, and there were no obstacles to plants and animals immigrating from the south. But already, between 6000 and 5000 B.C., the depression began to cause the formation of marshes in north-western Germany, so rapidly did the sea advance. And roughly a thousand years later the Channel Bridge broke down, still in the earlier Atlantic time, when human culture was changing from the latest Palæolithic to the early Neolithic.

The most important consequence of this event was that immigration by land was stopped immediately. Trees such as the beech, which spread over north-west Europe in the 2nd millennium B.C., could not reach the British Isles, and many experts believe that the few finds of beech in deposits of the last centuries are due to an introduction by man.

The Boreal period, rather dry and warm, brought a first invasion of steppe and forest steppe animals into Europe from the Pontic and Central Asiatic areas, as well as some Mediterranean or Lusitanian forms from South Europe. The early Atlantic time still allowed many animals to immigrate who preferred a more humid climate and wanted a higher temperature; but the invasion was stopped suddenly by the breakdown of the Channel Bridge. The Atlantic period was followed by another drier, continental phase, the Subboreal, lasting from 2500 till 500 B.C. The numerous newcomers from the Russian steppes which populated Europe then reached her western parts, but most of them could not cross the Channel. A fair number of these species has even survived the last climatic phase, the humid Subatlantic time (after 500 B.C.), in drier localities on the Continent as "steppe relics," but none of them seems ever to have touched British soil.

Thus we can state that animals (many insects especially) and plants requiring drier conditions and living in the British Isles must have populated them in the Boreal phase when the bridge existed. Those elements of the British fauna requiring warmth and some humidity arrived in the early Atlantic phase, and only a few species have managed to cross the Channel later.

Relics from the Arctic and Subarctic times during and soon after the last glaciation are still to be found in Scotland, such as the Varying Hare (*Lepus timidus* Linné) and the Ptarmigan (*Lagopus mutus*). Both species still inhabit Scandinavia and the Alps, and are frequently

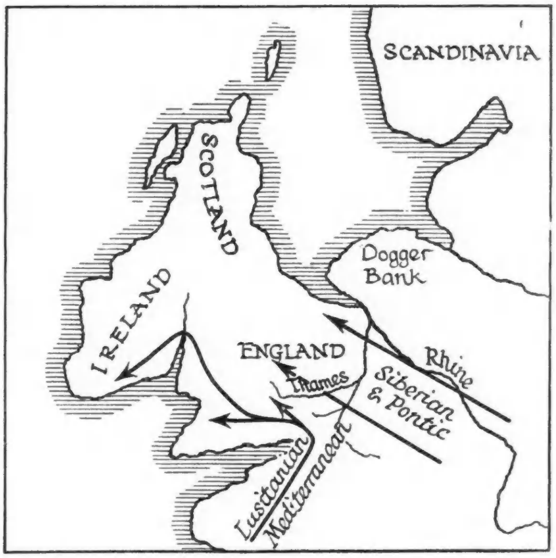
found in the Pleistocene deposits of England and Central Europe. There is no doubt that during the cold period they populated a vast area and that they retreated to their present localities when the climate grew warmer.

In the Boreal time the pine (*Pinus sylvestris*) had its optimum conditions of life and was very common in the British Isles, and numerous insects needing a warm and dry summer immigrated, together with the deciduous trees already mentioned. Many of these species had to retreat when the climate became damper with the beginning of the Atlantic phase. But the high temperature of the first part of this period still allowed the immigration of forms requiring warmth, and the humidity encouraged even Mediterranean forms to spread along the French coast of the Channel and to enter Britain. One of these seems to be the Strawberry tree (*Arbutus unedo*), now living only in the Mediterranean area and in South Ireland. Many of these immigrants naturally concentrated in south-east England, where the "bridge" was. It is also easily attributable to the situation of the bridge that more forms came from the east than from the west.

The Modern Phase.

Then the bridge was submerged, and the climate of the second part of the Atlantic phase became cooler, but remained humid. Mediterranean species like the *Arbutus* were compelled to restrict their area to the parts of the country having very little or no frost in winter, whilst the eastern elements, being more used to a cold winter, but requiring a warm summer, stopped their migration in the south-east corner of England. A very good example of this is the grasshopper *Metrioptera roeseli* Hgb. The stream of immigration was now dammed for all forms unable to cross the Straits by flying or swimming. Many a species that had not yet penetrated to the Continental coast of the Channel in the early Atlantic time, arrived too late to enter Britain, although the climate would be quite convenient and although it is abundant on the neighbouring continent in present days. There is, *e.g.*, another orthopter, *Ephippigera vitium* Latr., which lives in the Pontic and west Mediterranean areas, and in some places in Central Europe as a "Pontic relic," which obviously was spread over the whole of Europe in the Subboreal phase. It is still frequent in Normandy, but—having no wings—could not invade Britain. Another form that came too late and has attempted to invade Britain during the Subatlantic, is the Camberwell Beauty (*Nymphalis antiopa*), a well-known butterfly. C. B. Williams recently described in *Discovery* (February, 1935) how this form reaches the east coast chiefly in the autumn, probably coming from Scandinavia. The pretty insect finds a suitable climate in Britain, but apparently the immigrants are usually too weakened to give rise to new generations.

Thus, we see how the Straits of Dover proved an exceedingly important factor in influencing the British fauna and flora. However, it has not had the same significance for man. In the Atlantic period humanity had reached a high stage of civilisation; ships were certainly known and by their means the tribes on either side of the Channel were able to communicate.



Distribution of land and water in the Boreal period, with arrows indicating immigration-routes.

A close parallel to the development of the relations between England and the Continent is that of Ireland and Great Britain, a subject recently studied by J. K. Charlesworth. The Irish Sea was still much restricted in Boreal times, and the subsidence of the "bridge" took place during the Atlantic period, just as in the case of the English Channel. But not all the forms which had invaded England from the Continent had then reached the shores of the Irish Channel, so that the severance of Ireland and Great Britain resulted in preserving a poor, subarctic, and mainly boreal fauna and flora in Ireland. The common hare (*Lepus europæus* Pall.) does not occur in Ireland, and is replaced by a subspecies of the varying hare (*Lepus timidus hibernicus* Bell), a survivor from Arctic times. Of the British plants, only 67.5 per cent. inhabit Ireland at the present day.

Hooke's Combustion Theory.

By Douglas McKie, Ph.D., B.Sc.

One of the many puzzles in the history of science—a branch of learning much neglected in this country—is the oblivion into which Robert Hooke's theory of combustion was allowed to fall. No hostility was involved, but apparently simple negligence. Posterity is making some amends by the publication of Hooke's Diaries, which will throw much light on the early history of the Royal Society.*

THE tercentenary this month of the birth of that versatile genius Robert Hooke (1635-1703) recalls the many contributions that he made to the science of his day, more especially to mechanics, astronomy, and physics. Little attention, however, seems to have been given to his theory of combustion, although in some degree this remarkable work was a direct anticipation of the modern theory propounded by Lavoisier more than a century afterwards.

Robert Hooke was the son of the Rev. John Hooke, of Freshwater in the Isle of Wight, where he was born on July 18th, 1635. In infancy he was so weakly that his parents despaired of his life for several years; and in his youth he suffered from such severe headaches that his education in preparation for entering the Church had to be abandoned. At this period of his life Hooke, like Newton, was much given to the construction of mechanical toys: he made a wooden clock and a little ship with guns that fired. When his father died in 1648, Hooke, with £100 in his possession, came to London as apprentice to Lely, the painter, but shortly afterwards he entered Westminster School under the famous Dr. Busby, where he studied classics and mathematics. In 1653 he went to Christ Church, Oxford, as a servitor: he was "great in learning" but "small in other circumstances."

At Oxford Hooke soon attracted the notice of the philosophers of the "Invisible College," who had come from London to Oxford during the Civil War for "the Satisfaction of breathing a freer Air"; and presently he became paid assistant to the Hon. Robert Boyle, constructing for the latter the famous air-pump used for the researches described in his *New Experiments Physico-Mechanicall, Touching The Spring of the Air, and its Effects, etc.* (Oxford, 1660). Since some of the experiments carried out by Boyle with this apparatus were designed to throw some light on the problem of fire and flame, it may be that Hooke's interest in combustion originated in this work. All that we can say about Hooke's own ideas at this time is that in a tract entitled *An Attempt for the Explication of the Phaenomena, Observable in an Experiment Published by the Honourable Robert Boyle, Esq.* (London, 1661), he wrote that in the wicks of candles and lamps the oil or spirits or melted tallow "is dispersed and carried away by the Flame (which what it is, and how it consumes bodies, I shall on some other occasion by many luciferous Experiments manifestly prove) . . ." (p. 45): and this mere hint is all that Hooke made public before the appearance of his *Micrographia* (London, 1665).

In the *Micrographia* Hooke set out his theory of combustion in "Observation XVI" which bore the title "Of Charcoal, or burnt Vegetables." From the fact that wood subjected to great heat in a closed vessel was converted into charcoal without being consumed or burned away, provided that no access of air was allowed, Hooke concluded that air was the "universal dissolvent" of all "sulphureous," that is, combustible, bodies; that this dissolution occurred only when the combustible body had been made sufficiently hot; that this dissolution produced a great heat, commonly called "fire"; that the action was so violent that it brought the minute parts of the burning body into such rapid agitation that "the action or pulse of light" was produced in "the *diaphanous medium* of the Air"; that this dissolution of combustibles "is made by a substance inherent, and mixt with the Air, that is like, if not the very same, with that which is fixt in *Salt-peter*, which by multitudes of Experiments that may be made with *Saltpeter*, will, I think, most evidently be demonstrated"; that in this action some part of the body was dissolved by the air, just as any solute is taken up by its solvent; that other parts of the combustible were taken up by the air, but subsequently condensed therefrom; that some indissoluble parts of the combustible, as well as some dissoluble parts that had not become sufficiently heated, were carried up by the great violence of the action, as might be seen, for example, in soot, part of which on further heating was dissolved by the air, while part remained "fixt, terrestrial, and irrarefiable"; that some parts of bodies were so "sluggish and gross" that they could in no way be rarefied by heat and therefore formed what was known as ashes; that the dissolving parts of the air were few and a small amount of air was "quickly glutted, and will dissolve no more"; that if the supply of air was increased by means of bellows, it

**The Diary of Robert Hooke, M.A., M.D., F.R.S.*, 1672-1680. Edited by HENRY W. ROBINSON (Librarian to the Royal Society), and WALTER ADAMS, B.A. (London. Taylor & Francis. 25s.)

dissolved the burning body almost as violently as melted nitre did: and that there was therefore no such thing as an element of fire attracting or drawing up flame, but that flame was a mixture of air with the dissoluble, volatile, combustible parts of a body.

Hooke, however, gave no experimental demonstration of the truth of his theory and his promised treatise on the subject never materialised. Our further knowledge of his ideas is derived from passages and comments in his other and later publications. In his *Lampas* (London, 1677) he applied the theory to explain the consumption of oil in the wicks of lamps; the air dissolved the heated particles of the oil and this dissolution produced light. Of his theory he wrote at this time that "many Authors have . . . made use of it, and asserted it; nor have I yet met with one considerable objection against it." Other and more interesting references were made in his "Lectures of Light," read in 1680-1 and published in his *Posthumous Works* (London, 1705, edited by Waller), where he again spoke of his theory of the action of air on combustibles:

"So that 'tis the fresh Air that is the Life of the Fire, and without a Constant supply of that it will go out and die. Something like this is observable in the Life of Animals, who live no longer than they have a constant supply of fresh Air to breath, and, as it were, blow the Fire of Life: for so soon as that supply is wanting, the Fire goes out, and the Animal dies, and all the other vital Functions cease; as any one may presently see, if he puts a small Animal as a Bird, or the like, into a small Glass and covers it close; for in a short time the Air becomes satiated, and is no longer fit for Respiration; but though the Animal breath it as before, and Pant and move his lungs as before; yet if the Air be not fresh, the Fire of Life will extinguish. Some Learned Philosophers and Physitians have been of the Opinion, that the use of Breathing was for nothing else, but that by the Motion of the Lungs the Blood might be kept circulating which past through them, or that the Steams of the Blood might be carried off, which it could not do when it was full of Steams; but by many Trials I have proved that neither of those are at all the Cause of the Death of the Creature, but only the want of fresh Air."

Robert Hooke's air-pump, made for the Hon. Robert Boyle in 1658 or 1659.

Further, Hooke concluded in his "Discourse of the Nature of Comets," read before the Royal Society in 1682 and published in his *Posthumous Works*,

"that the Air it self is no farther the *Menstruum* that dissolves Bodies by Fire and Flame, than as it has such a kind of Body raised from the Earth, as has a Power of so dissolving and working on Unctuous, Sulphureous or Combustible Bodies: And this is the Aerial or Volatile Nitrous Spirit, which, provided it be supplied to the Body to be so dissolved, as by Fire, will work the same effect, even without Air. This is obvious in Compositions made with Salt of Nitre and other combustible Substances, as in Gunpowder, and the like, which will actually burn without the help of Air, as may be tried with it under Water; nay in an exhausted Receiver, as I have often tried, wherein the Effects are much the same, as if the same Accensions had been made in the open and free Air; though where this Nitrous part is wanting no Combustion, Dissolution or actual Fire will be produced, be the Heat never so great."

The subsequent history of Hooke's theory is obscure. It seems that the theory was not unacceptable to Hooke's contemporaries, although Birch's *History of the Royal Society* does not indicate any enthusiastic reception for it. Hooke himself had not met with any "considerable objection against it," as he says in *Lampas*. And the phlogiston theory had no great currency in England until the 18th century was considerably advanced. It may be that a belief in elementary fire was too deeply rooted in chemical thought for any serious recognition of the experimental validity of another explanation. It is none the less not easy to see why so few references can be found to this remarkable hypothesis. The ideas so clearly set forth by Hooke appear to have been unknown to Joseph Black, although John Robison, the editor of his posthumous *Chemical Lectures* (Edinburgh, 1803), made in the notes and observations that he appended to this work a just and generous tribute to Hooke's theory and to his labours in this field, adding: "I do not know a more unaccountable thing in the history of science, than the total oblivion of this theory of Dr. Hooke, so clearly expressed, and so likely to catch attention." And it is clear that Robison was thoroughly familiar with all that Hooke had written on this matter, since he refers to all the works in which Hooke had treated of it. Since Robison's day and until Professor T. S. Patterson (*Isis*, 1931, **15**, pp. 47 and 504) recently displaced Mayow from the prominent position he had been wrongly given during the 19th century in the history of chemistry, little recognition has been afforded to Hooke. The tercentenary of his birth is perhaps not too late for him at last to receive the credit due to him for his close anticipation of the current theory of combustion.

African Topics.

The June number of *The Geographical Journal* contains two articles of especially wide interest. Major R. E. Cheesman deals with Lake Tana and its islands, revealing facts about one of the least-known areas of a little-known country; and Professor E. P. Stebbing appeals for a concerted effort to stay the encroachment of the Sahara on the West African colonies, both British and French. In these days, when world-travel is coming to be regarded as commonplace, it is well to be reminded that we may expect "always something new out of Africa."

Asbestos in Modern Life.

By Conway Parr

After centuries of existence as little more than a mineral curiosity, asbestos has lately come into its own as an important adjunct to human comfort and safety. Scientific research has enabled manufacturers to use it in many unexpected ways, and our author here outlines some of the chief uses of this valuable material to-day.

RESEARCH chemists have just placed at the disposal of industry a complete range of brilliantly coloured, fireproof fabrics. They have discovered a method of dyeing asbestos fabric so that colours as vivid as those possible of achievement with cotton and linen can be obtained, which, in addition, remain unaffected by intense heat. This implies that fireproof materials can be substituted for practically every form of heavy duty cloth in common, and sometimes dangerous, usage. Already the new materials, which are being produced even in "pastel" shades, are finding extensive use as hangings, covers, and draperies in household decoration where proximity to fire is a danger.

It has taken more than two thousand years to bring about this fireproof blanketing of the world. The ancient Greeks first knew about the possibilities of asbestos; the modern Briton has commercialised it.

Asbestos is, in fact, a Greek word. It was originally used to signify quick-lime and Pliny gave it the meaning (not strictly correct) of "incombustible" when he chose it to designate the new ore that was being mined in Greece and in Italy. This mineral, a mixture of iron, calcium, magnesium, and aluminium silicates, originally attracted interest entirely as a curiosity, since it disintegrated on being rubbed between the fingers or rollers into fine, fibrous threads. As an amusing professorial "lecture trick," it can almost be said, the Greeks played with the idea of weaving these threads into small pieces of fabric. They succeeded, and the first known use of asbestos fabric was the manufacture of handkerchiefs that could be thrown into a fire to be burned clean after use. The next step was the more careful mining of the ore so that threads several feet in length were produced, and then asbestos was put to a more practical use: burial shrouds for bodies to be cremated were made of it, so as to ensure that the ashes of the body were kept separate from the ashes of the funeral pyre.

Charlemagne, later, had a table-cloth made of asbestos. Next, thin threads were used for lamp wicks, as they still are to-day in Greenland. A piece of the early fabric is preserved in the museum at the Vatican.

Nothing more is heard of it until 1671, when an English merchant, trading with China, exhibited a piece of what he referred to as "salamander's wool" at a meeting of the Royal Society. He had procured some raw asbestos and by the simple means of rubbing it between his hands had flaked the fibres into a soft, soapy-feeling cocoon like cotton wool.

Two workers in asbestos clothing, unharmed after a prolonged period enveloped in flames.

Two hundred years later the first commercial development came. Steam engines were revolutionising the world. Something had to be found that was not only fireproof but heatproof, if tremendous waste was to be avoided in the primitive furnaces that were first used with steam generators. Someone remembered asbestos and discovered that there were great deposits in

Italy and Corsica. The deposits were exploited, the ore being broken down and used in a crude way as the basis of plasters that would jacket steam containers. Asbestos became a mineral with a commercial future

To-day the greater part of the asbestos used in industry is mined in the Quebec province of Canada or in Griqualand West and Rhodesia, South Africa. Small quantities are found in Queensland, New South Wales and New Zealand, and there are evidences of its existence in Cornwall, North Wales, and Scotland.

To prove the efficacy of an asbestos suit, a worker places his head inside a white-hot furnace.

In different varieties, the fibres vary greatly in character. When silky and flexible they are sometimes known as " mountain flax," while " amianthus " is a term often used to denote the finer qualities. When the fibres are naturally interwoven, such names as " mountain leather," " mountain cork," and " mountain paper " are colloquially given to them. Mountain cork, needless to say, is light enough to float.

The asbestos formerly used was generally a fibrous form of some kind of amphibole. In recent years, however, most of the asbestos on the market is a variety of serpentine known mineralogically as crystotile. Both possess similar properties so far as resistance to heat is concerned, but the amphibole-asbestos, or hornblende type, has the greatest length of fibre. Some threads actually reach six feet in length, though they are often harsh and brittle and more difficult to use commercially. It is usually white or grey in colour.

The serpentine asbestos occurs in narrow veins yielding threads only two or three feet in length, but the threads have a great tensile strength. They are usually of a delicate silky lustre, are exceedingly flexible and elastic, and are of a yellowish or greenish colour.

The Canadian asbestos occurs in a small belt of serpentine, while the Asbestos Mountains in Griqualand West, Cape Colony, yield a blue fibrous mineral of a type similar to the amphibole variety. It is found in veins in slaty rocks associated with jaspers and quartz rich in magnetite and brown iron ore.

The rock is generally quarried and cobbed by hand before being crushed in rock beaters and passed between rollers. The rollers have a peculiar cross motion in addition to their parallel action, since it is essential that the fibres should be drawn apart as well as separated. The final process concerns washing and grading so that the more lengthy fibres can be sorted out for weaving purposes, and the small, broken ends left for crushing and mixing with plasters to make a fireproof substance that can be applied to flat or round surfaces—such as pipes or walls—in a moist state.

Lancashire spinning and weaving machinery is adapted for the manufacture of asbestos fabrics. Actually the mineral fibres are woven almost as easily as cotton, the only difference being that the looms have to work more slowly to cope with the increased brittleness of the mineral as compared to the vegetable product. When cotton threads are interwoven with the asbestos, as in some cheap special materials, they give a resiliency to the spindles that enables speeding up of manufacture to take place.

To-day there are plants in England turning out asbestos cloth by the thousand yards. Fireproof suits for firemen and airmen are made from it. In a recent test carried out by Bell's Asbestos at Slough, Buckinghamshire, a man wearing one of the suits and with boots, gloves, and helmet of asbestos stood in a fire that had been specially started with petrol and wood. He remained in the fire, at a temperature of 1500° Fahr., for $3\frac{1}{2}$ minutes with no unpleasant effects beyond a slight sweating. As soon as the first heat had cooled from his suit he was able to step out of it in safety.

With the gloves the man picked up a white-hot

bar of steel as though it were a cold poker and without feeling the heat on his hands. The British Air Ministry is buying hundreds of these gloves for the use of pilots and mechanics when a machine catches fire. They have already saved the lives of many men who might otherwise have met their death in burning aeroplanes.

That is the spectacular side of the use of asbestos. The more prosaic, but none the less vital, use concerns the fireproofing of the homes of England. Asbestos ceilings and walls that will confine fire to the room in which it originates are being incorporated in modern small dwellings by the hundred and at hardly any extra cost above the ordinary lath and plaster. Asbestos is beginning to serve as fireproof ferro-concrete for the poor man. With the fireproofing of the walls, the curtains and other hangings of a house can also be provided in the new dyed and brightly coloured asbestos fabrics that will not burn even if thrown on a fire—let alone if accidentally brought in contact with flame by the careless gesture of a child.

The fact that asbestos fabrics can be thrown on fires without burning has led to the production of blankets that can be carried in motor cars to drop on petrol outbursts and smother them, while a further step is the provision of asbestos blankets to take the place of the old-fashioned iron doors that, once closed to shut off a fire, could never be opened again without danger.

An asbestos blanket, rolled up to a ceiling and held by a thin strip of metal that will melt at a given heat, on the principle of the sprinkler water systems, and allow the blanket to unroll, is in use in many modern buildings and has been discussed for incorporation in the companionways of the giant steamship *Queen Mary*, launched on the Clyde last year.

Science and the Dinner Plate.

The common crockery plate seems an object of little interest, and the amount of skill and patience involved in the manufacture of good modern table-ware will come as a surprise to many readers. The article which follows is adapted from a paper in the Bulletin of the Ontario Research Foundation, the result of researches in their Ceramic Laboratory.

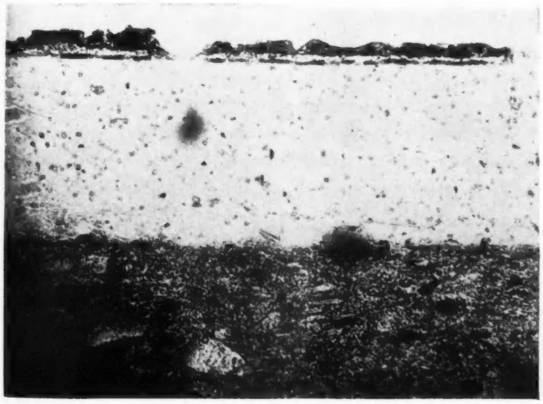
THE art of making crockery is one which had its beginnings in antiquity and reached a very high state of development long before the application of science to industry was a factor of importance. The story of the development of ceramics through the ages begins with the shaping of crude vessels of wet clay which acquired strength on drying. For a long period the type of ware produced depended on the accidental discovery of particular clay deposits, and higher and higher temperatures were used in order to improve its strength. Gradually experiments were tried in mixing clays and other materials, often brought from considerable distances for blending, in order to produce more artistic and useful ware. Finally, scientific research was brought to bear on the industry, with the result that, to-day, some new materials are used in the manufacture, wholly as a result of the scientific study of silicate minerals.

It must have been quite early in the development of table-ware that an effort was made to lend it an artistic as well as a utilitarian value, and this ability to serve both as a medium for artistic expression and for a useful purpose is still characteristic of the better grades. Long before the industrial revolution the industry had reached a high state of artistic and utilitarian development, based on painstaking trial-and-error experiments. It was an industry in which success or failure often hinged on the possibility of avoiding even minor variations in the raw materials used, and in the rather elaborate technique which had been established by long experience. To the layman it appeared to offer little opportunity for the application of science. Indeed, it was by a process of gradual change in which the methods of manufacture became less and less experimental and more and more scientific, rather than by a series of striking scientific advances, that the industry was finally won over to an appreciation of the possibilities of scientific development.

Even a fairly close visual examination of a typical dinner plate shows it to consist of three parts: an inner, porcelain-like, opaque to translucent, white mass, technically known as the body; a relatively thin outer envelope of clear glass, technically known as the glaze, and a design, usually applied on top of the glaze and known as overglaze decoration, but sometimes between the glaze and the body, as an underglaze decoration. These three parts of a semi-vitreous plate are shown in section in the first illustration. The pudding-like mass at the bottom of the figure is the body, the clear section immediately above is the glaze, and the pigmented parts floating on top of the glaze are sections through the decoration. The dark specks

shown in the glaze are due chiefly to small bubbles. Under higher power and with thinner sections it can be seen that the body also contains a considerable amount of glass and, in fact, consists of a mass of crystals arrested in various stages of solution and regrowth, floating in a sea of glass.

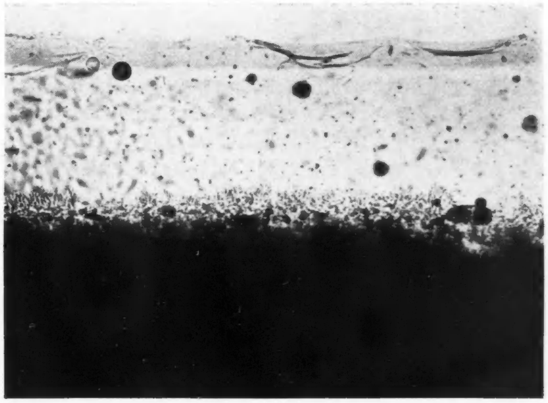
The possibility of producing table-ware, as we know it, depends on the property possessed by silicates of dissolving in each other at high temperatures to form liquids which, on cooling, do not recrystallise readily but become thicker and thicker, forming glasses, just as toffee cools to a hard, brittle, uniform mass without "sugaring." Apart from this property of forming glasses readily, the liquids resulting from the melting of silicates at high temperatures have a great deal in common with the ordinary solutions with which the chemist works at room temperature. For example, liquid silicates will deposit crystals just as strong brine solutions will deposit salt. This is illustrated in the photograph on the right, a thin section through the glaze and part of the body of a piece of Belleck china. Various minerals in the body have dissolved in the glaze when the ware was being fired, and have then formed a layer of crystals which is shown very clearly just where the glaze and body meet. The property of forming glasses on cooling is not restricted to silicates, however, since it has recently been shown that ordinary water will form a glass if



Thin section of semi-vitreous dinner plate showing body glaze, and decoration. (*mag.* x 145)

cooled with extreme rapidity under the right conditions.

The body of nearly all table-ware is made from mixtures of "clay substance" or "kaolin" ($Al_2O_3.2SiO_2.2H_2O$), felspar and silica, either introduced deliberately as such or by blending naturally occurring or artificially prepared mixtures, to which, in the case of English bone china, bone ash is added. The dry mixture is rendered plastic by mixing with water and is then formed into ware, which on drying develops enough strength to be handled. At this stage it consists of millions of very small but distinct mineral grains held together by forces not well understood. On



Thin section of Belleek china showing layer of crystals found between body and glaze. (*mag.* x 145)

firing, however, the different grains gradually melt, those melting first tending to dissolve the others until a considerable amount of glass is formed. At quite high temperatures, crystals of entirely new minerals gradually form in the glass, producing a network of interlaced needles. It is usual to fire the body to a fairly high temperature and then to coat it with a thin paste of finely ground materials which are to form the glaze. It is then fired again, usually at a lower temperature. Under the influence of heat, the glaze, initially a white powder, gradually softens and melts, usually puffing up like syrup that is spilled in an oven and then flattening down as the bubbles formed in melting become smaller and smaller, and the larger bubbles find their way to the surface and escape. In the case of porcelain, which is fired to a very high temperature, the body as well as the glaze forms a considerable amount of glass and produces bubbles. The relatively large bubbles in the glaze, seen in the third illustration, occur only at the junction of the body and glaze, and produce a slight "egg-shell" effect. When such a plate is examined with a microscope, or even a good magnifying glass, hundreds of these bubbles can be seen at the bottom of the glaze clinging to the body and looking like a large number of free balloons ready to start a race.

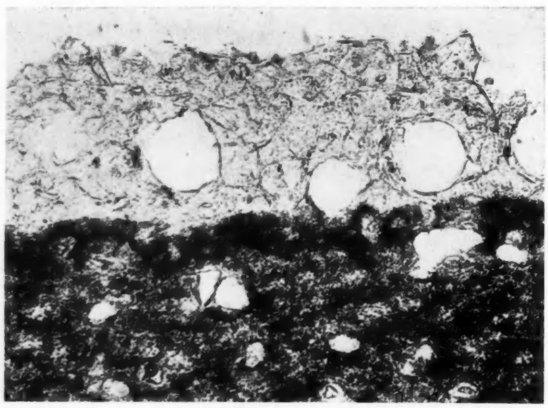
Underglaze decoration is, of course, applied to the body before glazing and has to stand the temperature

required to melt the glaze. It is, therefore, limited in its colour range. Overglaze decoration is applied to the fired glaze and then fired so that it melts and sinks into the glaze, making it permanent. Elaborately decorated ware may require many firings at different temperatures to fire all parts of the design correctly.

In addition to settling such fundamental problems as the changes produced when crockery is fired, scientific methods have been of great use in solving manufacturing problems of long standing. For many years a considerable proportion of ware was lost owing to a peculiar type of cracking which was apt to occur just as the ware was cooled below a low, red heat. Just why it should occur at so low a temperature and with the firing almost completed was a mystery. However, it has now been shown that when ware is fired above a certain temperature a very large number of extremely fine crystals of a mineral (cristobalite) are formed which have the peculiar property of shrinking very suddenly just below a low, red heat when they are being cooled. This was found to be the cause of the cracking.

Another source of trouble which depended on body composition was a peculiar random cracking of the glaze (known technically as after-crazing) which sometimes developed months or years after manufacture. This has been traced to a slow expansion of the body due to moisture absorption, which may continue for a year or more after the ware is made. Methods have been found for producing this effect in a few hours in the laboratory, and bodies and glazes have been developed which are not subject to this delayed cracking.

Sometimes it was the glaze rather than the body which was at fault. For instance, an occasional plate was found which, when used with silver utensils, acquired a series of distinct black marks which did not wash off readily. This defect had been associated for some time with the use of fuel containing more than a small percentage of sulphur in firing the ware, but beyond this little was known about it. A recent investigation of the subject revealed the rather remarkable fact that when a knife or other utensil was drawn over a smooth glaze, it did not actually touch the glaze but "skated" on a thin film of moisture. Thus all ware acquired silver marks if it was tested immediately after it was made and before it acquired a protective film of moisture. Glazes fired in kilns containing sulphur gases showed silver marking in spite of the moisture film. This was caused by extremely small craters on the surface of the glaze which tore microscopic particles of silver from the utensils, thus producing a distinct black mark.



Thin section of porcelain plate showing bubbles in both body and glaze (part of glaze has been lost in grinding). (mag. x 145)

Many of the highly prized properties of table-ware, such as translucency, purity of colour, thinness, beauty of decoration and gracefulness of form are obtained only by the use of materials and methods which allow very little leeway in the manufacturing operations. For example, some of the best ware is obtained by firing to a temperature just below that at which the ware will deform or develop other defects. Consequently, the potter is always glad of any help which research can give in avoiding defective ware.

That a weak, dull, earthy piece of unfired ware, which crumbles when brought in contact with water, should be transformed in the potter's kiln into a bright, hard, strong, and permanent article of beauty and utility has provided a fascinating mystery for mankind through many ages, a mystery which is now being rapidly solved by modern scientific methods without, we hope, robbing it of any of its fascination.

Psychology at the British Association.

On the occasion of the forthcoming meeting of the British Association in Norwich (September 4-11th), the President of the Psychology Section, Dr. Ll. Wynn Jones, has chosen as subject for his presidential address, "Personality and Age." Other aspects of personality and character are to be dealt with by various speakers, and an afternoon session is to be devoted to "Child Psychology." Memory, the place of mental image in psychology, the perception of distance, a problem of pictorial art, colour blindness, mental deficiency, psychological aspects of the technique of modern poetry are some of the subjects to be under discussion. In addition, three joint discussions with other sections have been arranged, one with Physiology on "Aids to Hearing," one with Education on "The Place of Psychology in the Training and Work of Teachers," and one with Engineering on "Applications of Science to the Control of Traffic." An evening discourse will be given by Dr. C. S. Myers on "The Help of Psychology in the Choice of a Career."

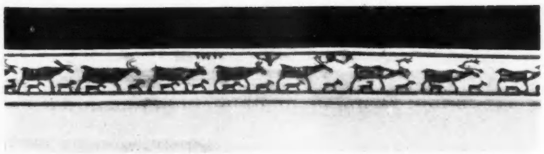
The Art of Primitive Peoples.

By E. N. Fallaize.

FROM more than one point of view the exhibition of primitive art at the Burlington Fine Arts Club has come as something of a revelation to those visitors, who, previously, had given no more than a casual attention to such of the products of the material culture of backward peoples as had come under their notice. The aesthetic expression and technical accomplishment of which the "savage" is capable are all the more striking when individual objects are taken out of the cultural setting in which they usually appear in museums and ethnographical collections and are shown as parts of a unitary exhibition in which the basis of selection has been artistic quality alone.

Except for some examples of textiles and one or two other small, but not unimportant, exhibits, this exhibition illustrates only the art of sculpture (including metal casting) and carving in wood, ivory, bone, or stone. As technique conditions performance in primitive, even more than in European art, it is not out of place to stress the fact that the high standard of "finish" shown by most of the specimens here has been attained in a stage of culture in which the use of metal is unknown and the only tools available are made of stone or shell.

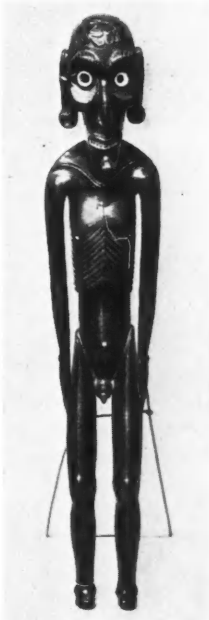
Aesthetically, as well as numerically, the West African section of the exhibition is the most important. Modern developments in certain schools of European sculpture have drawn attention to the principal characteristics of this African art. The examples now shown afford an excellent opportunity of appreciating and testing that feeling for form and the disposition and balance of mass for which it has been praised by the critics. Characteristic examples are to be seen in the Benin arts of bronze-casting and ivory carving, notably



Part of an Eskimo bow-drill, with typical minute engravings of caribou.

the carved ivory sistrum (No. 66), the flute player in bronze (68), the Portuguese cross-bowmen in bronze (69), and the carved ivory mask (110); but even more typical of Africa are the men and leopards and the elephants' heads, which form the decorative element in a pair of wooden chairs (4), and the wooden head-rest supported on two female figures from the Congo (126).

A realism of a different kind and more in accord with European standards is to be seen in the remarkable collection (34-64) of Eskimo carvings in ivory—human figures, male and female, arrow-straighteners, toggles, amulets, and pendants representing whales, seals, deer and other animal forms, which display a remarkable fidelity to, and feeling for, nature. No less, and in some ways even more, remarkable for their vitality and action are the minute engravings of groups of animals and hunting and fishing scenes, which appear on a series of fire bow-drills (48-54). In their vivid portrayal of characteristic attitudes of man and beast they recall the late palæolithic art of Spain.



An Easter Island statuette in wood. The extreme emaciation is noteworthy.

Before turning to the exhibits from the Pacific, mention may be made of a small case of miscellaneous objects from various parts of the world not represented elsewhere in the exhibition. Among these are bone needle-holders from Borneo (Iban) and New Guinea (138-140), showing a remarkable adaptation of an incised double-scroll pattern, examples of composite materials, such as wood, shell, and white clay, used for decorative effect (South America; 143-144), and the Ainu wooden moustache lifters carved in relief (150-151).

Although Pacific art stands out in the exhibition as second in importance to the West African alone, the homogeneity of the latter, which is modified only by local variations—minor schools of a major art—finds no parallel in the South Seas. Not only is there the broad distinction between Polynesia and Melanesia, but the art of each group and of almost each island has its distinctive character. Here too is to be noted the characteristic employment of decorative adornment on the commonest of articles of daily use, especially in wood. Hence the highly elaborated decorative patterns to be seen, for example, in the wooden club ornamented with triangle pattern from Fiji (133) or the wooden ceremonial paddle, of which the butt shows a series of conventionalised human figures from the Austral Islands (132). The decorative use of "mother-of-pearl" is well illustrated in the series of objects from the Solomon Islands (219-223).

Some of the exhibits from the Pacific have great

sentimental or historic interest. Among those from the Sandwich Islands, for example, is a feather-covered head with shell eyes, which was collected by Captain Cook on his last voyage.

The highly-finished art of the Maoris of New Zealand is represented by some excellent examples, among which the wooden figure-head for a canoe, in which a double-scroll design has in front of it a man with projecting tongue as a sign of defiance (258), illustrates a combination of ritual and decorative design which is characteristic. Particular mention may be made also of the statuettes in wood from Easter Island (206-208), which show an extreme degree of emaciation.

The exhibits from New Guinea include the valuable group from the little-known Sepik River area, of which it is difficult to say whether the artistic or the anthropological significance predominates. In this section the feather-mosaics on boards for ceremonial purposes (245), and the orating stool (33) stand out. Of these the former are unique, while the latter is remarkable in that, though it is beaten while the orator speaks, it may never be sat upon.

An exhibition of this kind represents something of a new departure for the Burlington Fine Arts Club; and the writer of the prefatory note to the catalogue has adopted almost an apologetic attitude in claiming the use of the term "art" for these exhibits. Such diffidence has proved unnecessary, as a visit to the exhibition will at once demonstrate. This art is "primitive" only in a conventional sense; to the anthropologist it is the end product of a long process of cultural development.

The exhibition will remain open until the end of July.

"O.T." For Swimmers

By W. McWilliam.

A NEW safety device will shortly be in use at most of the swimming pools in this country. Public attention has already been drawn to the efficacy of destroying bacteria in swimming baths by the addition of chlorine to the water. To obtain the fullest benefit from this process it is necessary for the correct proportions of chlorine and water to be maintained. The approved mixture is roughly about one part by weight of free chlorine to three million parts of water. This sounds like a formidable task for a skilled chemist to undertake, but fortunately the strength of the solution can easily be measured by what is called the "O.T." test. In this process a minute sample of the bath water is taken and "doped" by the mixture of a few drops of "O.T." (Ortho-Tolidine), a chemical which turns chlorinated water yellow, the depth of tint depending on the amount of free chlorine present.

In this new apparatus water from the bath is drawn up into a glass dome on a neat pedestal in full view of the public. The dome empties itself about every 15 minutes and automatically refills. Three glass flasks are mounted in the centre of the dome in line with each other. The water to be tested flows through the centre flask which fills and empties at the same time as the outside dome.

The "doping" of the sample water with "O.T." is carried out automatically and with perfect precision during the time it is in the centre flask, and the colour of the resulting mixture can be clearly seen from the outside. The other two flasks, one on either side of the sample chamber, are sealed containers of standard solutions coloured light lemon and deep yellow respectively, placed there for purposes of comparison.

So long as the colour of the doped solution is intermediate between those of the two permanent solutions, the amount of chlorine present in the bath water is within the safety limits prescribed by the Ministry of Health.

Young swimmers consulting the "O.T." apparatus installed on the side of a swimming-pool.

National Trust News

Londoners especially will welcome the news that steps are being taken to vest in the National Trust 200 acres of Selsdon Woods near Croydon, arrangements for purchase, maintenance, and management having been brought to a successful conclusion.

The scheme in its original form was started more than ten years ago by the Surrey Garden Village Trust with the object of saving as a nature reserve and bird sanctuary thirteen acres of Court Wood, the Addington section of the woodlands comprised in the Selsdon Park estate, which had come into the market owing to the death of the owner. The response was so encouraging that it was decided to form a purchase committee to endeavour to enlarge the area to be preserved.

Selsdon Woods are a fine and unspoiled example of the chalk scrub of the nearer Surrey Hills. Above the typical copses, with their wealth of bluebells, rise well-grown oak, beech, ash, and yew trees, and the woods are crossed by drives to which it will be possible to admit the public. The Woods afford a fine opportunity of securing a Nature reserve and bird sanctuary of outstanding importance to London. None of the areas so far available has been sufficiently large to serve as an open-air school where children and Nature students may be brought to study fauna and flora in natural surroundings on a large scale. It will not be possible to allow the public to roam at will through the woods, especially during the nesting and flowering season, but many sections as well as some miles of sheltered walks will be open to them at all times.

By securing Selsdon Wood naturalists have gained a possession that will be of incalculable value in the near, as well as in the more distant, future, and Greater London has acquired a most beautiful open space.

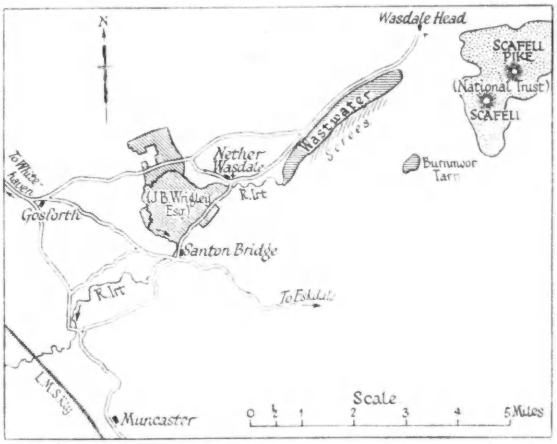
Hindhead and the Isle of Wight

The National Trust announce two further gifts of property. The first is an area of twenty-two acres of heather land with a few pine trees, near Waggoner's Wells, between Bramshott and Ludshott Commons, presented as a memorial to the late Mrs. Ada C. Vertue by her residuary legatees. This is a most valuable addition to the extensive properties already owned by the National Trust in and near Hindhead, amounting in all to over 1,500 acres. The National Trust is already indebted to Mrs. Vertue who in 1920 presented a stretch of land close to the present gift, which materially enhanced the value of the Waggoner's Wells property. The famous Waggoner's Wells ponds and adjacent woodlands were acquired in 1919 as a memorial to the late Sir Robert Hunter, first Chairman of the Executive Committee of the National Trust.

The other new gift is at St. Helens in the Isle of Wight. Here the Trust already owns some nine acres including the land known as "The Common," presented by Sir E. B. and Lady Poulton in memory of their children. Captain R. N. Bradish Ellames has now added to this gift a piece of land which originally formed part of the Common, and desires his gift to be recorded as a commemoration of the Silver Jubilee.

Land at Netherwasdale

It is announced that through the generosity of Mr. J. B. Wrigley over 1,300 acres of land in Netherwasdale, Cumberland, will be for all time protected from unsightly and ill-planned building or disfigurement by posters or advertisements by means of restrictive covenants entered into with the National Trust, who will become the owners of a small area to ensure the efficacy of the covenants. Mr. Wrigley's public-spirited action will safeguard the amenities of the roads leading to the Wastwater and of the fine views towards the lake and the head of the wild and unspoilt valley. This is a further interesting example of what is being done through the National Trust to preserve lands which, though not themselves suitable as open spaces for the use of the public, are important because interference with their natural features can easily spoil the magnificent views which are so large a part of the attractions of the district.



The new aquisitions at Netherwasdale, showing the relation to the National Trust Scafell property, and the way in which the approaches to the lake are covered.

The Charm of Estonia.

By Graham Carritt.

Those seeking to discover new ground for holiday-making might well follow the author's advice, and visit Estonia. Mr. Carritt is well qualified to give counsel, having lately returned from a " musical embassy " to the Baltic States, where he studied the folk song and dance that play a very real part in the life of the Estonian people.

For those who want a holiday out of the usual running, I cannot imagine a happier place to choose than Estonia. The towns of Estonia are extremely picturesque and full of historic interest, and the country has great charm and in certain parts is quite lovely. The roads are good, living is absurdly cheap, English is freely spoken, and it is possible to get there in a cargo boat for £2.

Estonia abounds in heathery moors and pine forests, in rivers and lakes and pleasant farm lands. There are hundreds of lakes in the interior, with green islands dotted about among them, and the winding rivers and streams, and the long wall-like cliffs rising from marshy plains make an unusually charming picture. This is essentially an agricultural country, and farms are numerous, the farmhouses strongly built and well kept, the fields and orchards around them fertile with crops and fruit. There are no mountains here, but for the most part gentle hills, that towards the south and south-east rise to a few hundred feet. Round about Tartu in the south, the Otepäa Heights provide some lovely scenery. It is among them that one of Estonia's biggest rivers, the Emajogi, rises, which ultimately flows into Lake Peipsi, one of the largest lakes in Europe.

A scene typical of the Estonian Countryside, a green island in a quiet lake.

The Estonians have many points in common with ourselves, not least a love of sport. They have always been famous for their wrestlers, of whom perhaps Hackenschmidt is best known in this country. Just outside Tallinn, the capital, there is a splendid stadium where athletic festivals are held. It occupies a lovely position, surrounded by sweet-smelling pinewoods and near to a fine sandy beach, where one can get a good bathe in the Gulf of Finland—and incidentally an excellent view of Tallinn. The stadium is used also for the national music festivals, which play so big a part in the life of Estonia. In the realm of sport again, the people share with us a fondness for horse racing and for yachting.

The sea coast of Estonia is very lovely and especially picturesque along the Finnish Gulf. Here there are high, rugged cliffs, with huge clefts in them, covered with luxuriant plants and shrubs. Udria and Narva-Jöesuu and Mereküla are among the most beautiful places on the coast, and Haapsalu, which used to be the summer home of the Russian Imperial family. Indeed, many of the former Russian aristocracy had their summer houses and estates along this attractive coast-line.

The cities of Estonia can scarcely be appreciated to the full without some knowledge of Estonian history. As long ago as 1345 the German Baltic Barons bought Estonia from the Danes. Later on she came under the dominion of Sweden for some 150 years, and later still, in 1720, Russia took over the country and kept it till 1917. In the circumstances it is cause for wonder that Estonian nationalism survived at all, but with the outbreak of Bolshevism the Estonians' chance came. Estonia declared herself an independent Republic in 1918, and this freedom she actually attained, but only after an heroic and agonising struggle. On one side the Bolshevists attacked her, on another the Germans, who were supposed to be attacking the Bolshevists. But every Estonian that could fight hastened to General Laidoner's banner, even students and schoolboys. The Finns went to help their kinsmen, and the British too. (That is partly why the Estonians long to know us better.) Ultimately Estonia came out victorious, and free.

With such a history it is only natural that the cities of Estonia should show traces of her foreign rulers, and one of their most striking features is the extraordinary variety of architecture. At Narva, for instance, the saying that " East is East and West is West, and never the twain shall meet " is quite disproved. Frowning at each other across the River Narva stand a Russian and a

Swedish fortress, the former planned on long extended lines suggesting space, the latter stockily built with strong, square central tower surmounted by pointed turret. In Tallinn itself there are even more and greater contrasts in style: the copper roofs and tapering spires of Swedish design, the rounded dome and cupolas of the Russian Church, the high gables of old-fashioned houses, the flat undecorated roofs of modern buildings. Tallinn is full of surprises, a picturesque and fascinating place. High up on a rocky hill stands the Castle, where now are the Government buildings, and around it and encircling the city are magnificent walls of tremendous thickness. Squat towers are dotted about here and there, some of them with quaintly humorous names—"Stout Margaret" and "The Peep into the Kitchen." The streets are sometimes so narrow that only one-way

Gymnastic displays, like this one in the Tallinn Stadium, are a favourite pastime of the Estonians.

traffic is possible, and often, as in Pikk Street, the narrowness is accentuated by the old high-gabled houses. many with imposing doorways and splendidly wrought doors. At one moment a stranger may find himself in a quaint old-fashioned quarter, the next in a progressive modern city with buildings of a very different character. To this type belongs the "Estonia," which stands at one corner of a wide square. The "Estonia" really consists of two buildings with fine, slightly bowed fronts, joined by a covered promenade overlooking a charming courtyard. The whole is both pleasing and impressive, and inside not only is there a fine theatre but a magnificent concert hall, spacious reception rooms, and a good restaurant. There are many striking buildings on modern lines in Tallinn, in Tartu, the University town, and elsewhere, serving to show how enterprising and progressive the Estonians are.

If entertainment is sought at Tallinn, there is always

At Narva the long, low wall of the Russian stronghold frowns across the water at the stocky square tower of the Swedish fort.

the theatre or the opera. The Estonians have some charming "operettes," too, which are excellently produced and without being heavy have much more in them than our average musical comedies. Some of them give an opportunity for the display of Estonian national costumes and folk dancing. There was a scene of this kind in "The Lady without a Country," which I saw when I was in Tallinn; the dresses were brightly coloured, like the Russian, and very beautiful, and the dancing was first class. There are also two excellent orchestras, which give winter and summer concerts alternately. But although these are undoubted attractions, I should not go to Estonia primarily on their account. I should go there because Estonia has natural attractions that other countries do not possess; the Estonians are a friendly people, and their land is unfrequented, unspoiled, and unexplored.

Correspondence.

IN MEMORY OF LAWRENCE.

To the Editor of DISCOVERY.

Sir,—It must have occurred to many of your readers that the memory of Lawrence of Arabia should be handed down to future generations in some suitable form. May I therefore suggest that no memorial of his life and work in Arabia could be more appropriate than the endowment of a Chair of Arabic in the University of London?

Yours faithfully,

H. ST. J. B. PHILBY.

Royal Geographical Society, S.W.7.

[A committee has recently been formed to deal with this and other proposals for a memorial to T. E. Lawrence. We strongly advocate some such scheme as the above, facilitating intercourse between Britain and the Arabic-speaking peoples.—ED.]

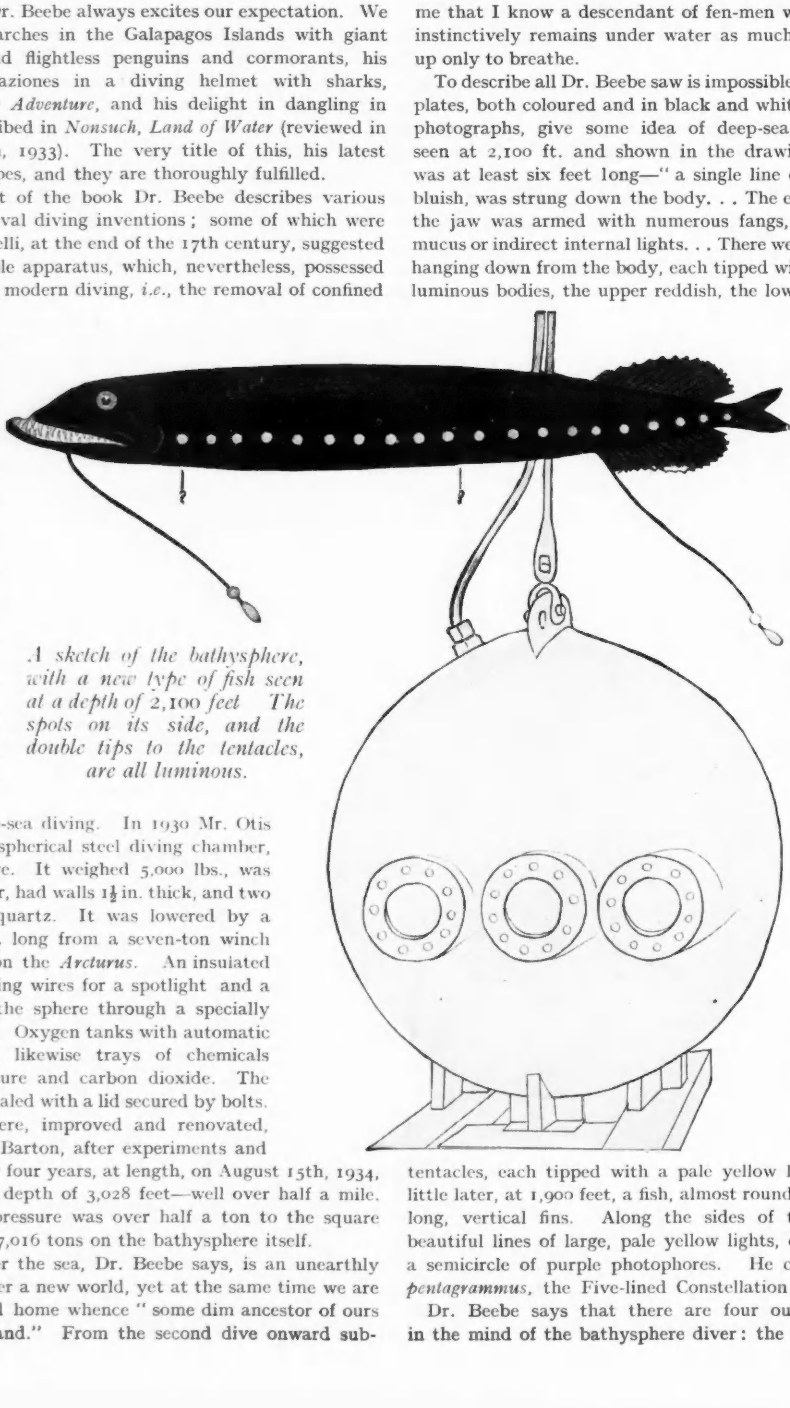
Book Reviews.

Half Mile Down. By WILLIAM BEEBE. (John Lane. 18*s.*)

A new book by Dr. Beebe always excites our expectation. We remember his researches in the Galapagos Islands with giant marine iguanas and flightless penguins and cormorants, his submarine conversaziones in a diving helmet with sharks, related in *Arcturus Adventure*, and his delight in dangling in similar attire, described in *Nonsuch, Land of Water* (reviewed in *Discovery* in March, 1933). The very title of this, his latest book, raises our hopes, and they are thoroughly fulfilled.

In the early part of the book Dr. Beebe describes various ancient and mediaeval diving inventions; some of which were actually used. Borelli, at the end of the 17th century, suggested a quite impracticable apparatus, which, nevertheless, possessed the germ-idea of all modern diving, *i.e.*, the removal of confined air and the substitution of fresh. The problem had been solved long before by the rat-tailed maggot, with its telescopic tube reaching to the surface, and by some water spiders.

The depth limit for a diving helmet is 60 ft. and for a diving suit 306 ft. A submarine has descended 383 feet, and a diver in a metal suit 525 feet, but thus heavily clad a man is almost helpless. All these devices are inadequate for deep-sea diving. In 1930 Mr. Otis Barton designed a spherical steel diving chamber, called a bathysphere. It weighed 5,000 lbs., was 4 ft. 9 in. in diameter, had walls $1\frac{1}{2}$ in. thick, and two windows of fused quartz. It was lowered by a steel cable 3,500 ft. long from a seven-ton winch used by Dr. Beebe on the *Arcturus*. An insulated electric cable, carrying wires for a spotlight and a telephone, entered the sphere through a specially packed stuffing-box. Oxygen tanks with automatic valves were fitted, likewise trays of chemicals for absorbing moisture and carbon dioxide. The exiguous door was sealed with a lid secured by bolts.



A sketch of the bathysphere, with a new type of fish seen at a depth of 2,100 feet The spots on its side, and the double tips to the tentacles, are all luminous.

In this bathysphere, improved and renovated, Dr. Beebe and Mr. Barton, after experiments and trials extending over four years, at length, on August 15th, 1934, plumbed the record depth of 3,028 feet—well over half a mile. At this depth the pressure was over half a ton to the square inch and a total of 7,016 tons on the bathysphere itself.

Adventuring under the sea, Dr. Beebe says, is an unearthly experience. We enter a new world, yet at the same time we are returning to the old home whence " some dim ancestor of ours rawled out upon land." From the second dive onward submersion seemed as reasonable and the environment as familiar as if he could recall his ancestral memory; and this reminds me that I know a descendant of fen-men who, when he bathes, instinctively remains under water as much as possible, coming up only to breathe.

To describe all Dr. Beebe saw is impossible. The very beautiful plates, both coloured and in black and white, and the numerous photographs, give some idea of deep-sea marvels. The fish seen at 2,100 ft. and shown in the drawing reproduced here, was at least six feet long—" a single line of strong lights, pale bluish, was strung down the body. . . The eyes were very large; the jaw was armed with numerous fangs, illumined either by mucus or indirect internal lights. . . There were two long tentacles hanging down from the body, each tipped with a pair of separate luminous bodies, the upper reddish, the lower one blue." Such was *Bathysphæra intacta;* the Untouchable Bathysphere fish.

In another dive in August, 1934, at 1,500 ft., a large fish swung suspended, half in, half out of the beam of the spotlight. It was something entirely unknown; two feet in length, unluminous, with a small eye and good-sized mouth. Its colour was " an unpleasant pale olive drab, the hue of water-soaked flesh . . . a colour worthy of these black depths." Dr. Beebe named it *Bathyembryx istiophasma;* the Pallid Sailfin. Even more weird was the Three-starred Angler fish, seen during the same dive at 2,470 feet, a new species, 6 inches long, oval, black, with small eyes, and 3 small tentacles, each tipped with a pale yellow light organ. And a little later, at 1,900 feet, a fish, almost round, with a big eye and long, vertical fins. Along the sides of the body were five beautiful lines of large, pale yellow lights, each surrounded by a semicircle of purple photophores. He called it *Bathysidus pentagrammus*, the Five-lined Constellation fish.

Dr. Beebe says that there are four outstanding moments in the mind of the bathysphere diver: the first flash of animal

light, the level of eternal darkness (varying from 1,700 to 1,900 feet according to sun-power), the discovery of a new species of fish, and the explanation of some mysterious occurrence. Thus, during the record depth dive, he discovered that the sudden "explosions" near the window of the bathysphere, which had often puzzled him before, were clouds of luminosity or bursts of individual sparks emitted by deep-sea shrimps in self defence.

The ultimate depth reached showed an increase in the number of large fish and a correspondingly greater number of lights. But when the lights were thickest Dr. Beebe thought of the lightless creatures invisible to him, and those blind from birth to death.

The book contains appendices which give detailed descriptions of the bathysphere and its contents; unedited telephone observations on two of the dives; a classified *résumé* of the organisms observed; and a summary with conclusions.

To convey all the charm and fascination of this amazing volume in a short review is impossible. It opens up a new world, both to the specialist and to the amateur. Both will read it with delight.

E. W. HENDY.

Orthohydrogen, Parahydrogen and Heavy Hydrogen. By ADALBERT FARKAS. (Cambridge University Press. *12s. 6d.*)

This book, of which the shorter title "Light and Heavy Hydrogen" appears to the present reviewer to be preferable to the longer one above quoted, is the fourth volume of the Cambridge Series of Physical Chemistry. As general editor of that series, Professor Rideal is to be congratulated upon having persuaded Dr. Farkas to write an account of recent work in a subject to the development of which he and his brother have contributed so much. The result, according to the dust cover, is "the first book about heavy hydrogen." The claim is strictly correct, although monographs, some of them approaching book length, have recently appeared in several languages. Thus in 1933 Dr. L. Farkas wrote in German an account of ortho- and parahydrogen and this was followed in the next year by an equally exhaustive account of heavy hydrogen by Frerichs. Shorter monographs appeared in France in 1931 and 1934 on the same two subjects, Professor Darmois being author of both of them. Finally, almost simultaneously with the appearance of the present book, a complete survey of the work on heavy hydrogen was published by Urey and Teal in America. The non-specialist may well enquire how this new interest in an old subject came to be aroused and ask to be enlightened further concerning the three qualifications here applied to hydrogen—for him, until now, the name of the very simplest of the chemical elements.

In part the answer to his enquiries is simple, in part it is of a more recondite nature. Hydrogen is now known to be an isotopic mixture, not a pure element. In itself this fact is startling only because it has so long remained unknown. Most chemical elements exist in nature as mixtures of isotopes. But the hydrogen isotopes, because of a large disparity in mass, may be easily separated: in this hydrogen is unique and for this reason names are required for the two fractions resulting from the separation. We may call them light and heavy hydrogen, respectively. All but about one hydrogen atom in ten thousand is of the former variety. The terms ortho and para, on the other hand, apply to molecules, not to atoms—and the distinction which they imply is the harder to explain. Many other than hydrogen molecules exhibit these physically distinct forms, although in no other case has separation so far been effected. However, both light and heavy hydrogen give ortho- and paramolecular forms—which explains the preference as to title already expressed.

This, then, elaborates slightly, for the non-specialist, the adjectives newly applied to "hydrogen." Possibly he would gather very little else by reading the volume under review. To the research worker, however, if he has to deal with hydrogen as a physicist or physical chemist, it will be indispensible; for it fulfils a very real need. Soon, no doubt, the development of the chemistry—organic and inorganic—of heavy hydrogen will give rise to a similar need. We may hope that, when that occurs, it will be as adequately satisfied.

N. FEATHER.

Low Temperature Physics. By L. C. JACKSON. (Methuen. *3s.*)
High Voltage Physics. By L. JACOB. (Methuen. *3s.*)
Relativity Physics. By W. H. McCREA. (Methuen. *2s. 6d.*)

These latest additions to Messrs. Methuen's series of *Monographs on Physical Subjects* place physicists still further in debt to the publishers. Like the Tabloid products of a well-known firm, each volume is a marvel of compression within an easily portable compass—they can, however, hardly be assimilated with quite the same rapidity and ease.

In his *Low Temperature Physics*, Mr. Jackson notes with satisfaction the recent revival of English interest in this field of research. His treatment of the subject is admirably developed, He first deals briefly with modern methods of producing and maintaining very low temperatures, including that based on the adiabatic demagnetisation of paramagnetics by which a temperature of .05°K. has been reached—the lowest yet attained. The measurement of low temperatures is then treated. The student will be properly grateful for the clear indication given of the technique employed. The authoritative account of the properties of solid and liquid helium, of calorimetric methods at low temperatures, and of the fascinating transition of metals into the super-conducting state when near to absolute zero, cannot fail to be of value to the student and absorbing interest to all readers.

In *High Voltage Physics*, Mr. Jacobs takes his readers into an extreme region of another kind. By high voltages, he intends us to understand electric pressures of ranging from a thousand to a million or more volts and his little volume is concerned generally with the behaviour of matter when subjected to such voltages. A short summary of the methods used to produce these abnormal voltages forms the subject matter of the introductory chapter. An account of methods used for their measurement follows. Mr. Jacobs continues with an indication of the rich harvest already yielded by research on the properties of both "high voltage" electrons and positive ions with particular reference to methods of inducing artificial nuclear disintegration of elements. He concludes with an excellent account of the behaviour of air, solids, liquids and the vacuum respectively as dielectrics when under high electric stress.

In *Relativity Physics*, Dr. McCrea manages within some 83 pages to show us the leaven of relativity at work in the mass of physical concepts—a feat of drastic but exquisite surgery. Seeing that the influence of the General Principle of Relativity is hardly felt till we enter the domain of astronomy, the author

confines himself to a consideration of the influence of the Special or Restricted Principle. He very clearly shows how potent is this postulate that all Gaussian reference systems are equally suitable for a statement of physical laws. Establishing first the Lorentz transformation, the necessary revision of concepts in kinematics and mechanics is tersely made. In the field of optics, the hypothesis of light quanta is shown to be consistent with relativity principles. Electromagnetic theory, atomic physics, and thermodynamics are each in turn considered as regards their reaction to the injection of the Special Principle. While obviously compression has been severe, the student should find the book most helpful in making accessible to him the results of the impact of the theory of relativity in diverse directions.

All three books are well printed, well diagrammed, and satisfyingly indexed and all contain very complete bibliographies for further reference.

Physical and Dynamical Meteorology. By DAVID BRUNT. (Cambridge University Press. 25s.)

The reader of Professor Brunt's text-book is left in no doubt that modern meteorology is an advanced branch of mathematical physics. Out of twenty chapters, only two or three are descriptive, and some of the others contain fifty or a hundred differential equations, with the analysis leading up to them. This makes stiff going, but fortunately the mathematics is not arid; when the reasoning has been grasped one usually feels that something has been gained which could not have been conveyed in mere words. There are a few slips, and in some places the treatment could perhaps have been simplified, as in dealing with the mixing of two masses of damp air, but these faults are almost inevitable in the first edition of so ambitious a work.

The scope of the book is comprehensive, no less than an analysis of all the changes which occur in air moving horizontally or vertically, the causes which initiate these movements and the factors which limit them. The movements studied range from turbulence on various scales up to cyclones and anticyclones and the circulation of the atmosphere as a whole. The author opens in a quiet way, Chapter I being: "The facts which call for explanation. A sketch of the surface distribution of the meteorological elements over the globe" (but why "surface" when several pages are devoted to the vertical distribution of temperature?). In Chapter II among other things we are introduced to two of the author's main pre-occupations, water vapour and potential temperature in relation to stability. The next chapter elaborates the part played by water vapour, while Chapter IV, "Thermodynamics of the atmosphere," brings in the concept of entropy and that invaluable tool of the meteorologist in the upper air, the "tephigram"—temperature (T) and potential temperature (ϕ). For relief we have a descriptive chapter on radiation, a subject which Professor Brunt has himself done much to advance in recent years. This is followed by "Radiation in the troposphere," in which we have several examples of remarkable agreement between calculation and observation, and the difficult problem of "Radiative equilibrium and the stratosphere," including the strange phenomena connected with ozone.

The next four chapters deal with steady motions in the atmosphere, beginning with the general mathematical theory, which is developed in 70 equations, and continuing via the gradient wind and discontinuities to winds in general. The finer structure of the wind is discussed under the heading of turbulence, a subject in which some striking experimental work has been done recently, leading to unexpected results. Brunt has an exhaustive knowledge of the literature, and his treatment is wonderfully up-to-date.

Chapter XV synthesises the preceding pages; the incoming energy from the sun is traced through its transformations into potential and kinetic energy and the dissipation of the latter in turbulence. So small is our working capital and so heavy the "overhead" that if the income of energy were withdrawn the whole system would be brought practically to a standstill in six days. Barometric depressions are discussed, first from the mathematical standpoint and then in their modern guise as interacting air masses, the forced ascent necessary to give rain being related to dynamical instability instead of to thermal instability as in the older theories. The corresponding subsidence and its results are described in a chapter on "Anticyclones," and finally all these motions are brought together in "The general circulation of the atmosphere." So the plan is completed and the book is rounded off in the grand manner. In the atmospheric engine there are many wheels within wheels, but the conscientious reader will have gone far towards understanding why and how they revolve.

C. E. P. BROOKS.

The Physical Basis of Things. By JOHN A. ELDRIDGE. (McGraw-Hill. 22s. 6d.)

This is an excellent popular discussion of Physical principles. It shirks none of the difficult topics; relativity, kinetic theory, quanta, spectra, the nucleus, and the new mechanics are all discussed.

Analogies are very freely used, but surprisingly little harm is done, and those who like models better than equations get good value.

There is plenty of "uplift," and a tendency to make our flesh creep at the prodigious appears at times, but English readers will be used to this by now. Chapter headings such as "Atoms *à la* Bohr" do not do their contents justice. All the same these things can be overlooked in a book which is otherwise so successful. It can be recommended strongly to all classes of readers of *Discovery*.

Photoelectric Cells. By NORMAN ROBERT CAMPBELL and DOROTHY RITCHIE. (Pitman. 12s. 6d.)

The previous edition of this book appeared in 1930; in the four years which have since elapsed so much change has occurred in this branch of physics (as indeed in most branches) that the authors have thought best entirely to rewrite the book. For example, since the last edition the so-called rectifier cell has been developed, with its great convenience of being able to dispense with batteries.

Not only has the subject-matter changed; the public has become more accustomed to the use of photo-cells, so that less emphasis now needs to be put on the practical side, and more attention can be paid to the theory. The authors have written their book primarily for those who desire to understand photo-cells. Thus when they discuss the uses of cells they shorten the account by describing types of application, grouping them under

the headings of absorption, photometry, and colorimetry. Discussion of particular problems occurs at length only when important principles are involved. After reading this book one should be in a position to understand present applications and to choose what is, in the judgment of the authors, the right cell and most appropriate auxiliary apparatus for a particular use.

It is clear that the authors are writing from first hand experience; repeatedly their own preferences are indicated, with reasons for their choice, and this critical attitude enhances the value of the book. Another result is that emphasis is laid on certain aspects of particular interest to the authors. For example, in the chapter on photometry great attention is given to the attainment of precision.

The authors have not sought to make their account complete, but give references at the end of each chapter, with remarks on the subject matter of the references. To some the chapter on current measurement might have been made more helpful still by the inclusion of more information about galvanometers and their choice, but the authors take the view that this method of current measurement is too familiar to warrant the space. An interesting feature of the book is the number of helpful suggestions for enabling amateurs to construct their own instruments.

This book can be recommended to those who are interested in photo-cells and their applications and want to use them intelligently and to those who are not primarily interested but who wish for a book on the subject to which they may refer.

The Indus Civilisation. By ERNEST MACKAY. (Lovat Dickson. 6s.)

This is the second of Messrs. Lovat Dickson's new series of archæologies. The discovery in the Indus Valley of a highly developed civilisation dating back to the first half of the third millennium B.C. is among the most surprising of the advances of modern archæology, and we must particularly welcome this book from the pen of the man who has excavated the principal site of the new culture. Apart from articles on particular aspects of the excavations, the only hitherto published work dealing generally with the Indus Civilisation is the monumental publication under the editorship of Sir John Marshall—which is beyond the reach of most individuals and, indeed, within the scope of few libraries.

The first site where this civilisation was recognised was that of Harappa which had for years served as a brick quarry and even as a source of railway ballast. When the importance of the finds thus brought to light by chance came to be recognised other sites were sought out and a long chain of them was discovered between the present course of the Indus and the foothills of the Khirthar Range in Baluchistan, while indications were found of the spread of the culture beyond this area. The main evidence of the Indus Civilisation comes from the site most fully excavated—Mohenjo-daro, "The Place of the Dead"—smaller than Harappa but yet covering a square mile of ground. In one place excavations were carried on to a depth of forty feet below the surface but the lower archæological levels were inaccessible because of flooding. The time span seems to have been about five hundred years, the upper levels dating to 2550 B.C., and right from the beginning of this period the inhabitants were in a bronze-using state of civilisation. Who these inhabitants were is not clear, but they were certainly a pre-Aryan people, and, among the small account of skeletal material to hand, four races have been identified.

The people of Mohenjo-daro led peaceful lives, though there is evidence of their having been attacked at one period of their history. They lived in an organised state of society having had a scheme of town-planning, as evidenced by the regularity of the lay-out of the city, and the most complete ancient drainage system as yet discovered, while large baths, the use of which may have been in part ceremonial, were among the buildings unearthed. Of particular importance as dating material and as evidence of trade are the connections found to have existed between the Indus and Babylonia and other centres of ancient civilisation.

The general reader and the specialist will find much of interest in this book, and one must note with regret that the investigations with which it deals have, in common with other archæological exploration in India, been suspended on financial grounds.

Tell el-Amarna. By JOHN PENDLEBURY. (Lovat Dickson. 6s.)

Sound judgment has been displayed in the selection of Tell el-Amarna as one of the first of the sites of excavation to be described in this excellent little series of archæologies projected by Messrs. Lovat Dickson. Akhenaten who founded the city as the centre of his reformed and universal religion, which was to transcend the bounds of Egypt, is a figure of perennial interest. Mr. Pendlebury, however, has not allowed him to dominate the picture unduly. Archæologically, the significance of Tell el-Amarna, as revealed in recent excavation, does not lie merely in its interest as the centre of a new heretical religion. The work of the Egypt Exploration Society on this site, of which Mr. Pendlebury is now the field director, has afforded an unusually intimate view of the conditions of life of the private citizen and of the general standard of culture of the people. In this account, brief as it is, the author has been singularly successful in giving a bird's eye view, adequate for the purpose of the series for which he writes, of all the most important types of building which have been found up to the time of writing, palace, temple, official building and dwelling house. It is not without interest to note here that the temple, of which the excavation has been completed this season, has been found to exceed a kilometre in length.

In a book of this compass no exhaustive account of the two great fields of Akhenaten's innovation, religion and art, is possible; but the main points, the individual and subjective elements in both, are well brought out. Of the history of the XVIIIth dynasty enough is told to give a background.

Mr. Pendlebury has written an attractive and informative little book which, like his well-chosen illustrations, should whet the appetite of the reader who is not already an Egyptologist for more. Some account of the exhibition of "finds" from Tell el-Amarna arranged by Mr. Pendlebury was given in *Discovery* in November, 1934 (p. 319).

Land of Women. By BARONESS KATHARINA VON DOMBROWSKI. (Putnam. 7s. 6d.)

This book belongs to the class of semi-historical novel which relies for its attraction largely on a wealth of lurid and revolting detail. With this reservation it must be admitted that it gives an interesting picture of life in Paraguay during the middle of the last century, when a series of ruthless dictators brought the

country into a deadly conflict which in its duration and futility had something in common with the present war in the Chaco.

The story centres on the schemes and vices of Don Francisco Lopez and his Irish-Parisian mistress, Madame Lynch, a calculating, egotistical courtesan who goads his ambition, especially during the war, and so affects the destiny of the people that she comes to be fanatically hated. Dreams of becoming the Napoleon of South America led Don Francisco into a seven years' struggle with Brazil, Argentina, and Uruguay which lasted from 1864 to 1870. Worse than the casualties of the war were the unspeakable tortures and death penalties inflicted on his subjects at the slightest suspicion of treason, or merely for purposes of revenge. When, finally, after the defeat of his army, the dictator is killed by the enemy we are told in a publisher's note that "what remains of the Guarani people—a horde of ragged and famished women who had followed their men into the field—are relieved of their scourge and turn in revenge on his mistress."

The title of the novel is certainly justified: according to Akers's *History of South America*, whereas the population of Paraguay in 1863 was over 1,300,000, eight years later it was reduced to 220,000, of whom only 28,000 were men. But it is a little difficult to believe that the crowd of women who attacked Madame Lynch's carriage can have been quite so numerous or ferocious if they allowed the object of their hatred to escape aided only by a coachman and his whip.

Mid-Ice: The Story of the Wegener Expedition to Greenland. By JOHANNES GEORGI. (Kegan Paul. 12*s.* 6*d.*)

Watkins' Last Expedition. By F. SPENCER CHAPMAN. (Chatto and Windus. 15*s.*)

There is a tragic resemblance in these stories of scientific exploration in Greenland, because in each case the leader of the expedition, a man of high ability and world-wide reputation, lost his life in the service of his comrades during the earlier stages of the enterprise. At this point, however, the resemblance ceases, and in all other respects most striking differences are to be seen. The English expedition was a small adventure of four young men, who had served in an earlier expedition of 1930 and 1931 and who returned to Greenland in the summer of 1932 through sheer enthusiasm to continue the work that the earlier expedition had started. The German expedition, on the other hand, was much larger, much more abundantly equipped, and perhaps also more purposeful. It planned to undertake comprehensive scientific studies of the geology of Greenland, the structure of its immense ice cap, and the meteorological phenomena which that ice cap is believed to produce. One of its principal objectives was the establishment of an observation station on the inland ice at a distance of 250 miles from the landing place on the west coast.

The hazards of the country levied a bitter toll on both expeditions. On August 20, 1932, before the British expedition had established itself in permanent winter quarters, its leader, "Gino" Watkins, perished alone while hunting for seal in a kayak. His three colleagues determined to continue the work which he had planned, and Mr. Chapman's book tells in curiously impersonal fashion the story of their experiences and adventures. Even after reading his account of a year of intense activity, which was at times of great danger, the author and his two companions still appear as little more than mere surnames without clearly depicted personality or aims. Such self-effacement is probably a typically British characteristic. The German book, on the other hand, is much more revealing, and it is written for a single clearly-stated purpose. Dr. Georgi spent a year as meteorological observer at the station on the central ice and was there entirely alone for more than one-third of that time. Through adverse climatic conditions only two supply trains succeeded in reaching the station; when Dr. Georgi and his winter companion, Dr. Sorge, took stock of their resources after the arrival of the second train, they concluded that, while their stocks of food would be sufficient for two or even three men, they could not prudently remain there throughout the winter unless they received further supplies of fuel and other stores by a definite date and they sent back to their leader, Dr. Alfred Wegener, to this effect. But after this letter had been dispatched they found that their small sledging equipment was most dangerously ill-suited to a return and that by most stringent economies in their stocks of fuel they could continue at the station through the winter and perform its all-important scientific work. Meanwhile Wegener, before receiving their message, had started for mid-ice at the head of a third and last train of supplies. It proved impossible for this third train to get through; the supplies were dumped and most of the men were sent back. On October 31 Wegener and two companions arrived at mid-ice, without food or petroleum, after a journey of forty days through temperatures as low as —65° F. One of the three men was so seriously frostbitten that it was imperative to leave him at mid-ice; but Wegener and a Greenlander companion were still in good condition to face the hazards of a return journey, and accordingly, after their sledges had been replenished from the scanty stocks at mid-ice, they hastily set out again on a journey which Georgi describes as a race with death. Both men lost the race; Wegener died of heart failure and his companion disappeared without trace in the snow.

The occurrence of such a disaster on each of these expeditions clearly raises a general question of the responsibilities and duties that the leaders themselves may properly assume. Watkins died because he was undertaking the risks of hunting for his companions; and with a party so scantily furnished it may have been unavoidable that he as the most experienced member (rather than as the leader) should face those risks. On the other hand, Wegener—hard as it may seem to say so—appears to have sacrificed himself without adequate cause. It is questionable whether he should have placed himself at the head of the third supply train, just as it may be questionable whether Scott should have placed himself at the head of the polar party in 1912; but the graver mistake was made when he decided to press on to mid-ice with his two companions, even when he supposed that his arrival there could not possibly bring help but might increase the danger. At this point he should have resigned himself to the task of leaving the mid-ice party to its fate, whatever that fate might be. From the moment when they had first volunteered for the service, and again when they decided to carry on through the winter with severely restricted supplies, the members of the mid-ice party had freely accepted the risk of perishing there unaided and alone; and their leader should have left them to bear this responsibility entirely by themselves, instead of going forward for no more useful purpose than to assure himself as to what their decision might be. The most lasting lesson of both books is the high importance of a leadership which preserves itself safe and intact for the direction of the enterprise as a whole and which delegates to its subordinate members the responsibility for the performance of specific arduous and dangerous tasks.

C. PAYLING WRIGHT.

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